Iron and Steel Engineer

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J. F. KELLY, *Editor*

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A RADIO SALUTE

To The

Engineers of the Iron and Steel Industry

A radio program sponsored by the Westinghouse Electric & Manufacturing Company and dedicated to the Engineers of the Iron & Steel Industry will be broadcasted Sunday evening, 9:45 o'clock Eastern Daylight Saving Time, May 31, 1931.

The accomplishments of the Engineers of the Iron & Steel Industry will be described in a program over a chain of 26 N. B. C. Radio Stations.

This program will lead to a short address by Mr. F. O. Schnure, President of the Association of Iron & Steel Electrical Engineers, in which the work of this Association will be described.

A suitable musical background for the portrayal of the interesting story of the accomplishments of the Iron & Steel Engineers will be provided by a 40-piece orchestra and vocal unit. The program will be broadcasted over the following stations:

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KYW—Chicago
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WFAA—Dallas
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WDAY—Fargo
KPRC—Houston
WREN—Kansas City
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KSTP—Minneapolis
WSMB—New Orleans
WJZ—New York
WKY—Oklahoma City
KDKA—Pittsburgh
WHAM—Rochester
WOAI—San Antonio
KWK—St. Louis
KSTP—St. Paul
WBZ—Springfield
KVOO—Tulsa

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AT

ASSOCIATION OF IRON & STEEL ELECTRICAL ENGINEERS

Convention and Exposition

JUNE 15-19, 1931

CLEVELAND, OHIO

MONDAY, JUNE 15, 1931

Business Session.
Electrical Developments.
Arc Welding.
Standardized Symbols for Control Apparatus.
The Application of Health Lamps to the Iron and Steel Industry With Respect to Efficiency and Welfare.
Opening of Iron and Steel Exposition.
Informal Reception at Cleveland Auditorium.

TUESDAY, JUNE 16, 1931

Special Committee on Bearings Report.
Motor and Control Equipment for Cold Strip Mill Drives.
Twin Motor Drives.
Boat Excursion—Lake Erie.

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Practical Side of Metallurgical Heating Application.
Combustion Control Apparatus for Open Hearth Furnaces.
Electrical vs. Mechanical Devices Used in Control of Open Hearth Furnaces (7 papers).

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Lubrication Engineering Committee Reports on

Roll Necks
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Cranes.
Machine Tools.
Electrical Generating Equipment.
Motors.
Turbines.
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Conductors of Heavy Alternating Current.

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Heat Treating.
Bright Annealing and Galvanizing.
Wire Mill Management.
Wire Mill Cost Accounting.
Lubrication and Application of Tungsten Carbide Dies.
History of Wire Industry.
Manufacture of Insulated Wire and Cable.
Rust Protection of Wire Products with Cadmium.

IRON & STEEL EXPOSITION

CLEVELAND PUBLIC AUDITORIUM

JUNE 15-19, 1931

Open Monday, 1:30 P. M.	Closes 10:00 P. M.
Open Tuesday, 1:30 P. M.	Closes 5:30 P. M.
Open Wednesday, 1:30 P. M.	Closes 5:30 P. M.
Open Thursday, 1:30 P. M.	Closes 10:00 P. M.
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Electrical Auxiliaries in Steel Mills *

By D. W. DEAN †

The casual observer in passing through a steel plant sees the red hot steel going through the roll stands, and marvels at the huge electric motors that drive the roll stands. The large main drive equipment gets the attention, just as the star football player gets the applause. But a star football player can seldom win a game without the essential teamwork and support of his teammates. Likewise a rolling mill cannot prove an economical producing unit without well planned auxiliary equipment. Back of the spectacular main drives must be an army of small motors with their special controllers for manipulation of the steel and for finishing processes.

Few steel plant executives appreciate the fact that their investment in auxiliary electrical equipment frequently exceeds the investment in main roll drive equipment.

In one Cleveland steel mill, where the major products are billets, sheet bar, and merchant bar, the following shows a comparison between the main drive and auxiliary electrical equipment:

	Number	H.P.
Motors Driving Roll Stands	11	31,760
Auxiliaries—		
D.C. floor motors, exclusive of coke works and blast furnaces	174	6,392
Crane Motors	275	9,100
Estimated for D.C. motors in coke works and blast furnaces	25	1,000
Estimated for A.C. motors	100	4,000
Total for Auxiliaries	574	20,392

Based on an investment of $20 per horsepower this plant has approximately $645,200 invested in main drive motor and control equipment. Based on an investment of $25 per horsepower for auxiliary motors and control, this plant has approximately $509,800 invested in auxiliary electrical equipment. In this case the auxiliary equipment is 80% of the main drive investment.

In another steel mill in the Cleveland district, where billets, sheet bar, sheets and strip represent the major product, the following shows a comparison between the main drive and auxiliary electrical equipment:

	Number	H.P.
Motors Driving Roll Stands	18	27,250
Auxiliaries—		
Floor motors, A.C. and D.C. exclusive of coke works	552	24,280
Crane Motors	216	8,865
Total Auxiliaries	768	33,145

Based on the same investment values as previously used, this plant shows an investment of $545,000 in main drive motors and control, and $828,625 in auxiliary motors and control. In this case the auxiliary equipment is 150% of the main drive investment.

The June 1930 Iron and Steel Engineer shows the following comparative analysis of main drive motors and auxiliary motors for a large steel plant in the East:

	Number	H.P.
Motors Driving Roll Stands:		
D.C. Reversing	12	64,500
D.C. Continuous	3	4,500
A.C. Continuous	5	5,550
Total	20	74,550
Motors for Auxiliary Drives:		
A.C. Floor Motors	953	34,057
D.C. Floor Motors	1,530	64,398
D.C. Crane Motors	965	44,992
Total	3,448	143,447

In this plant the total HP. in auxiliary motors is approximately twice the HP. in main drive motors. Based on the same investment charge per horsepower as previously assumed it will be seen this steel plant has approximately $1,491,000 invested in main drive and $3,586,000 invested in auxiliary electrical equipment. This ratio of 2.4 for auxiliary investment to main drive investment is probably higher than for the average steel plant, but it does emphasize the importance of the auxiliary equipment.

Frequently when electrical equipment is being purchased for a mill the electrical department would like to spend several thousand dollars over a minimum quotation to obtain some special features in the auxiliary equipment to provide improved operation. Difficulty is frequently met in securing approval to buy the higher priced equipment. We might consider one or two applications where the auxiliaries are of outstanding importance to emphasize that the electrical department should be permitted broad authority in the purchase of electrical auxiliaries.

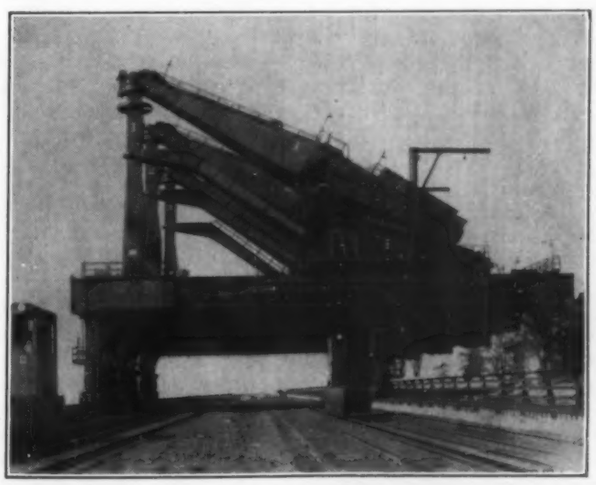

FIG. 1—Three ore unloaders at C. & O. docks, each using 8 motors, totaling 1060 HP. with variable voltage control for the main hoist and trolley travel.

An analysis was made some time ago of the operation of a 40" blooming mill. Such a mill is earning its "board and room rent" only while metal is in the rolls. The analysis showed that metal is in the rolls less than 32% of the total time consumed in rolling an ingot. By spending $5,000 for improved screwdown control the percentage time that metal is in the rolls can be boosted to 35% or better.

* Presented at Cleveland Section Meeting, Association of Iron and Steel Electrical Engineers, January 23, 1931.

† Steel Mill Engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

Thus the time the metal is in the rolls can be increased almost 10% (3% divided by 32%), which, for this mill, would mean an increase of approximately 9,000 tons per month. Assuming the blooming mill represents a $1,000,000 investment with 20% annual fixed charge, the $5,000 investment in improved auxiliaries will decrease the fixed charges per ton to such an extent that an annual savings of more than $10,000 can be shown, returning 200% on the investment.

Another example could be cited in cold roll strip reel drives. As the industry goes to high speed rolling it becomes increasingly necessary to use modern electrically driven constant tension reel drives following the roll stand. A four-stand tandem mill of moderate size will represent an investment of approximately $200,000. The modern take-up block, or strip reel, will represent an investment of $7,000, complete with electrical equipment. A cheaper strip

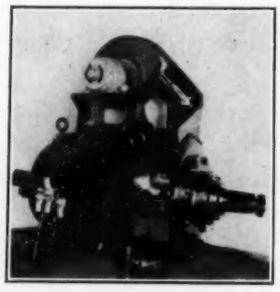

FIG. 2—350 HP., frame 165, type MC motor for beam hoist of ore unloader. Note that the motor is force-ventilated by a separately driven fan mounted on the motor.

reel drive can probably be installed at half the cost, such as the variable tension drive where the reel, or take-up block, is chain driven from the mill. But when you put $200,000 into a modern mill you want to use that mill to the best possible advantage. Experience has shown that the high delivery speeds of the modern cold strip mill cannot be obtained without suitable constant tension take-up block equipment. So the 1% to 2% savings in investment on the take-up block drive will be obtained at the expense of tonnage. From 5% to 10% greater tonnage and a more uniform product will be obtained by the use of the electrically driven constant tension take-up block.

I think it will be agreed that the slightly higher cost that is sometimes necessary to secure the best possible auxiliary equipment can usually be justified. You gentlemen, the representatives of the electrical department in your plants, should not hesitate to insist that the auxiliaries for your various projects be given the consideration that they deserve.

I do not believe you are interested in any long and detailed theoretical discussion of steel mill auxiliaries. You are interested in what your fellow engineers are doing. We will, therefore, discuss some recent developments in auxiliary drives.

ORE UNLOADERS

Figure 1 shows three ore unloaders recently placed in operation at the C. & O. docks at Presque Island near Toledo. These unloaders were built by the Wellman Engineering Company. The following will give some idea of their huge size: The main girders are about 120 feet long, the stiff-leg has an overall height of approximately 60 feet, and the beam is about 95 feet long. The combined capacity of the three unloaders is 3600 tons per hour, and the actual time for unloading a 10,000 ton boat is 4 or 5 hours. The bucket capacity is 17 tons.

Each unloader uses 8 motors totalling 1,060 HP. The beam hoist has a 350 HP., 500 RPM., shunt wound frame 165 type MC motor. The trolley travel motor is a frame 100 MC, 170 HP. shunt wound motor. The bucket closing and opening motor is a 2-speed wound rotor frame #100 type MA alternating current mill motor rated 125 HP/150 HP., 900/1200 RPM., forced ventilated. For the leg rotating drive a 25 HP. totally enclosed squirrel cage motor is used. A 150 HP., frame #80 type MA motor drives the unloader bridge, and a type MA motor of the same rating drives the hopper disc. The larry car travel uses a 50 HP., type MA-50 wound rotor mill motor, and the larry car gate is driven by a 50 HP. totally enclosed squirrel cage motor.

Variable voltage control is used for the two main motions, beam hoist and trolley travel. Alternating current motors are used for all other motions.

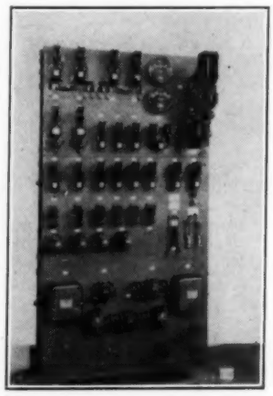

FIG. 3—Variable voltage control panel for the 350 HP. motor and generator for beam hoist.

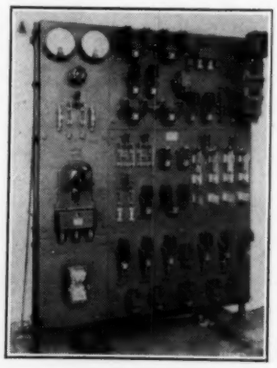

FIG. 4—Variable voltage control panel for two 150 HP. mill type motors and motor-generator set for skip hoist.

The motor generator set has a 200 KW. generator for the beam hoist motion and a 125 KW. generator for the trolley motion, the two generators being driven by a 500 HP. 900 RPM. synchronous motor. The motor generator set is mounted inside of the beam and serves to help balance the stiff-leg weight.

SKIP HOISTS

Variable voltage skip hoists are not new, but the number of inquiries received for this type of equipment indicates an increasing interest in this subject.

The Mingo Junction Works of Carnegie Steel Company are just completing the installation of a variable voltage skip hoist. This is a single skip with a maximum unbalanced load of 21,000 pounds, and a maximum rope speed of 500 feet per minute. The skip is driven by two 170 HP., 275 volt, 500 RPM. frame 165 type MCO shunt wound motors,

with variable voltage control from a 400 KW., 550 volt generator.

The disadvantages and advantages of variable voltage skip hoist have been previously discussed in the Iron & Steel Engineer, and will only be briefly summarized here:

Disadvantages:

1. Increased first cost.
2. Greater space requirement.

Advantages:

1. Definite free running speeds, empty or fully loaded bucket.
2. Definite slowdown speeds regardless of load.
3. Distance and time for slowdown portion of cycle is a minimum.
4. Simple control, rugged and inexpensive to maintain. Large capacity contactors with expensive renewal parts are eliminated.
5. Elimination of excessive strains on cables, sheaves, bearings, and steel structure.
6. Reduced mechanical maintenance.
7. Savings in power.
8. Elimination of large and expensive D.C. feeder lines by higher voltage A.C. circuit.
9. Greater flexibility to meet changing conditions of capacity and cycles.
10. Safe under all conditions, including overload, overspeed, voltage failure, failure of brakes, and overhauling load.

SOAKING PIT COVER CONTROL

The recent interest in soaking pit cover controllers, where the covers are operated from the pit crane cabs, will justify the following brief description of a typical installation.

The covers are normally operated from the soaking pit crane cab. However floor master switches are conveniently located so that the heater can open any cover when he so desires.

Single wire control from the crane cab is used for the covers. Opposite each row of pits is a short section of trolley rail for each of the four pits in a row.

In normal operation the proper master switch is placed in the "on" position as the crane approaches the pit from which an ingot is to be withdrawn. As the crane comes over the row of pits the cover is withdrawn and automatically brought to rest in the full open position. The ingot is then withdrawn. The cover may then be closed by centering the master switch, or by moving the crane away from the pits. Note the door will automatically close when the crane is moved away, regardless of the master switch position.

The crane operator also has control of the ingot buggy through single wire control.

In planning this installation the designers had three things in mind. First, the best installation that experience and materials could provide. Second, conservation of time, fuel, labor and space. Third, minimum operating cost. Results have demonstrated that these desired features have been attained.

When the new mills at Illinois Steel Company, South Works, were being planned their engineers desired to operate the pit covers from the crane cab. It was decided to eliminate the control trolley rail. A photo-electric method of control is used. A light source is mounted on the crane, and opposite the row of pits, mounted on the crane runway structure, is a light relay. When the crane is over the pit the operator presses a foot operated push button to energize the lights, and the beam of light acting on the light relay closes the control contacts to open the cover. When the operator next presses his foot operated button the cover closes.

The advantage of operating the soaking pit covers and ingot buggy from the crane cab can be summarized as follows:

1. Heat conservation. The covers are not opened before the craneman is ready, nor do they remain open after the ingot is deposited or withdrawn.
2. The ingot is conveyed rapidly to the mill as delays incident to the co-ordination of several operators are eliminated.
3. As the covers and ingot buggy are under control of the operator there is less possibility of damaging the crane due to inadvertent operation of the covers or the buggy.
4. Reduction of wear on the soaking pit cranes and conservation of power due to moving the ingot buggy rather than the crane.

SCREWDOWN CONTROL

It is common practice to use two mill type motors for the screwdown drive on blooming and slabbing mills. Sometimes the control is arranged to operate the two motors in series; or in some cases the motors operate permanently in parallel; or in still other cases the control is arranged so that the motors operate in series for "down" movements, and in parallel for "up" movements so as to obtain high speed in resetting the mill for the next ingot.

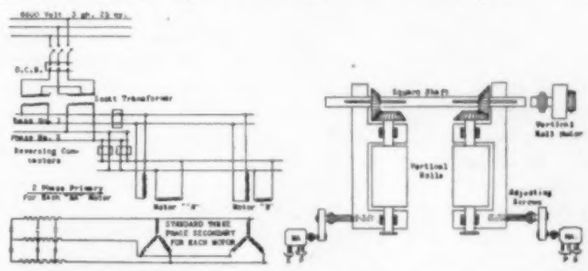

FIG. 5—Synchronous tie for vertical roll adjusting screws using one 150 HP. type MA wound rotor mill motor for each screw. The adjusting screws operate in synchronism by interconnection of the motor secondaries.

The 40" blooming mill at Gulf States Steel Company is used not only for rolling blooms but quite frequently for rolling slabs. When rolling slabs, the edging pass requires a roll screwdown adjustment of considerable magnitude in the "up" direction, and the next pass requires a screwdown adjustment of from 12" to 19" in the down direction. It was suggested that the control be arranged for the screwdown motors to operate in series for all minor adjustments, say from 2" to 5", either up or down, and if the master switch is left in the "on" position for more than ¾ second to 1 second the control automatically functions to place the motors in parallel. This gives the advantage of low momentum and high accuracy for the normal small adjustments on the screwdown settings so that they can be made in a minimum of time with excessive "inching" avoided. But for the screwdown adjustments of more than a few inches

a time relay functions to place the motors in parallel so that the major adjustments are made in the least possible time. This has proven a very satisfactory method of screwdown control where slabbing schedules are rolled.

The vertical roll screwdown for universal mills has usually been driven by one or two motors, with a mechanical connection serving as a tie between the two screws. On a recent universal slabbing mill the cross-connecting shaft was an undesirable feature and the Westinghouse engineers suggested the two screws could be tied together electrically, eliminating the cross-connecting shaft. Each screw is to be driven by a 150 HP., 440 volt, 25 cycle wound rotor mill motor, type MA, with the secondaries connected together so as to synchronize the two drives. The connection will be clear from the illustration.

We should not leave the subject of screwdowns without mentioning variable voltage control. On the new 52" beam mill at South Works of Illinois Steel Company the roughing mill has 3 automatic screwdowns, each driven by one 60 HP., frame 70 type MCA motor, shunt wound. Each motor has variable voltage control, with a 120 KW. generator supplying energy to the motor.

The Westinghouse Company has supplied seven variable voltage screwdown drives for recent installations and the electrical engineers feel that this is a decided forward step in screwdown control. Large sluggish contactors are eliminated; the drive is fast and "snappy"; electrical maintenance is reduced; there is an appreciable power savings; instantaneous peak torques are eliminated and there will apparently be appreciable savings in mechanical maintenance.

BLOOM SHEARS

There has been renewed interest lately in the direct geared motor for bloom shears, the motor starting and stopping for each cut, no clutch being used. We believe the first installation of this nature was made in 1924 using a 185 HP., frame 103 type MC motor for a 10"x10" bloom shear. However this type of drive did not come into general favor until the last two years and several installations of this nature have now been made. This method of drive eliminates a bad bearing situation that is always present for the clutch drive, and eliminates clutch maintenance and the delays that are occasionally caused by the clutch drive. With properly applied electrical equipment delays on the shear are very infrequent. For the ordinary size of bloom shear the direct geared motor application will undoubtedly be generally used for future practice.

LARGE SCRAP PIPE CRUSHING AND SHEARING EQUIPMENT

The Birdsboro Foundry & Machine Company have supplied two large shears to one of the pipe manufacturers for crushing and shearing low carbon cold pipe up to 26" diameter with ¾" wall thickness. The shear is driven by a 325 HP. frame 165 type MC motor with special control. Fig. 6 is a shop view of this shear. For tubes 20" diameter and smaller the shear can run continuous, making 12 to 15 cuts per minute. When crushing and shearing the large size pipe up to 26" diameter the shear is suitable for 6 to 8 cuts per minute. The 1 hr. rated current on the motor is 1025 amperes, and cutting peak may be approximately 3000 amperes, a maximum torque relay acting to take the motor off the line if the motor current reaches a point where shear stresses may become excessive.

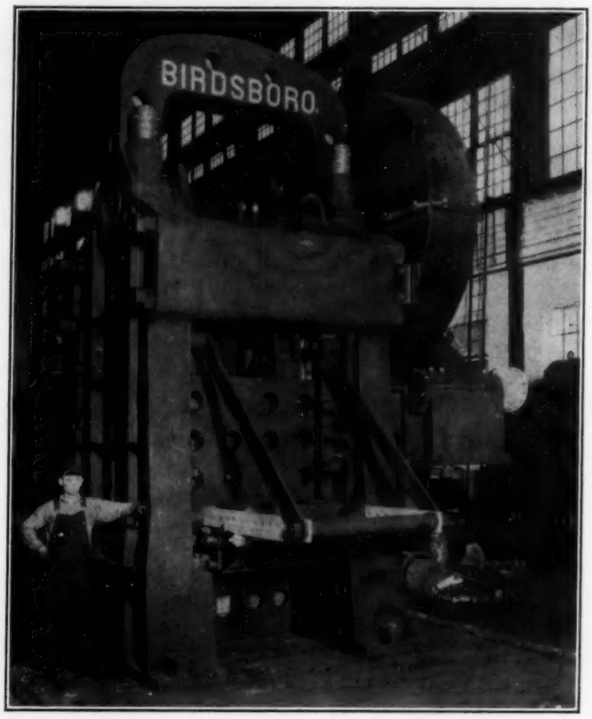

FIG. 6—Large shear for crushing and shearing cold scrap pipe up to 26" diameter, using 325 HP. frame 165-MC motor. Shear motor starts and stops for each cycle on larger pipe.

COLD STRIP REELS

Reference was made in the early part of this paper to cold strip reels. As cold strip steel leaves the finishing rolls it must be reeled under considerable tension for best results. Fig. 7 illustrates a typical illustration. This 20" mill has a reel drive suitable for 7000 pounds tension, the reel being driven by a 75 HP. low inertia planer type SK motor. A generator is coupled to the 250 HP. motor that drives the mill, this generator supplying power to the reel motor so that the voltage applied to the reel motor armature is proportional to the mill speed.

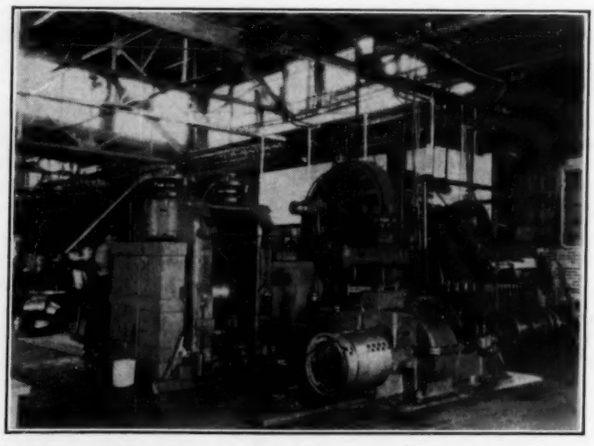

FIG. 7—Electrically driven strip reel for a 20" cold strip mill at Superior Steel Corporation.

The reel must slow down as the strip builds up on the reel. This feature is accomplished by having a vibrating relay control the reel motor field strength, this relay being responsive to the motor armature current which is proportional to the tension on the strip. In this way the strip is reeled under constant tension. The mill can be adjusted throughout the speed range without effecting the tension. Any tension from practically zero to the maximum for which the equipment is designed can be obtained by a turn of the tension rheostat handle.

The desirability of the electrically driven strip reel (or take-up block) will be apparent to one familiar with cold strip mills. One 300 HP. strip reel drive for 23,000 pounds tension is now being built for a non-ferrous strip mill, and a 400 HP. drive is contemplated for a cold strip steel reel.

ELECTRO-PNEUMATIC CONTROL

Rapid reversals, or inching service, is frequently required on auxiliary applications where the motor ratings are so large that the required high capacity magnetic contactor are too sluggish for the operating cycle required. The answer to such an application is electro-pneumatic control.

A structural mill roll straightener recently installed required a 400 HP. 230 volt direct current motor for reversing service, with reversals every 3 to 10 seconds. The use of carbon circuit breakers was out of the question due to the frequent opening and closing required. The large magnetic contactors that would be required would be sluggish in action and have high maintenance. Fig. 8 shows the 400

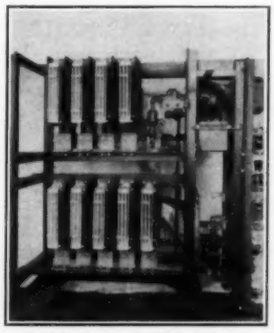

FIG. 8—400 HP., 230 volt reversing and plugging electro-pneumatic controller for structural mill roll straightener.

HP. 230 volt, reversing and plugging electro-pneumatic controller supplied for this application. Fig. 9 shows a contactor with one side of the arc box removed. The contactor consists essentially of a pair of contacts with suitable current carrying parts, strong magnetic blowout structure, an air piston with an insulated connection to the moving contact support, the cylinder for the piston, and a small electric valve that controls the air supply to the cylinder. When the valve coil is energized air is admitted to the cylinder and the piston acts to very rapidly close the contacts. However this rapid closing is accomplished without appreciable shock as the latter part of the piston stroke is against a considerable spring pressure, the spring absorbing the inertia of the moving parts as these parts come to rest in the closed position. This high spring pressure is very effective in the rapid parting of the contacts when the contactor opens, a factor in low maintenance. An air cushion absorbs the energy of the moving parts when the contactor opens. Note this cushioning of the moving parts in both closing and opening is an important factor in the low mechanical maintenance of these contactors. The fact that the contactors are designed primarily for railway service where they are continually subject to considerable vibration makes it necessary that the electro-pneumatic contactor be especially rugged mechanically.

For the electro-pneumatic controller shown in Fig. 8 the knife switch and relays are mounted on ebony asbestos panels supported from the same frame work that supports the contactors. This frame work also supports the small reservoir tank that assures a constant pressure air supply to the contactors. Accessories include a strainer and suitable reducing valve.

A Pittsburgh steel mill has recently specified electro-pneumatic control for an ore bridge and steel mill engineers will undoubtedly follow this installation with interest.

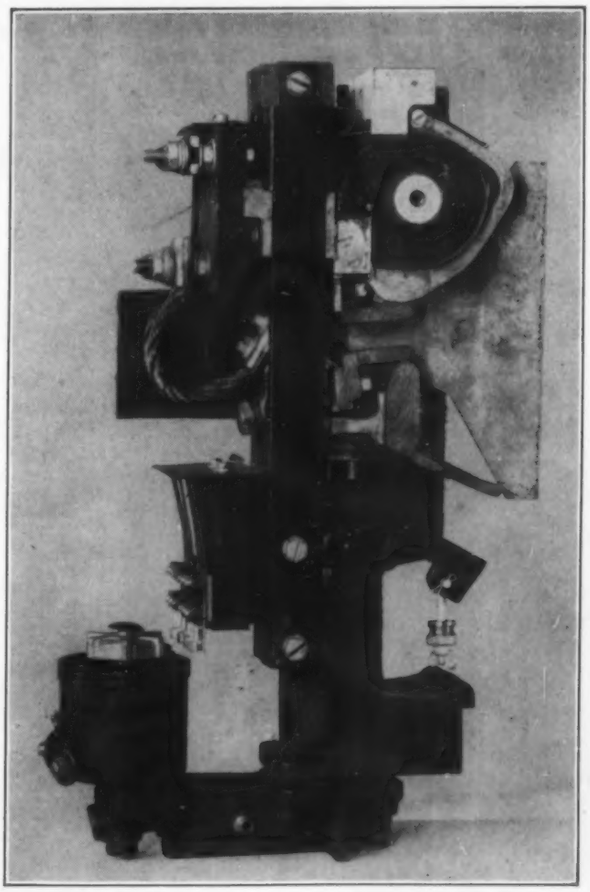

FIG. 9—Electro-pneumatic contactor with one side of arc box removed.

Conclusion:

The successful steel plant of the future will be the one that maintains a well planned program for improvements in their auxiliary drives, as well as for their main drives. When we consider one 15 HP. or 30 HP. motor and control the matter seems of minor importance. But when we consider that the total investment in electrical auxiliaries usually exceeds the total investment in main drives it becomes apparent you are justified in giving a considerable portion of your time and attention to the electrical auxiliaries in your steel mills.

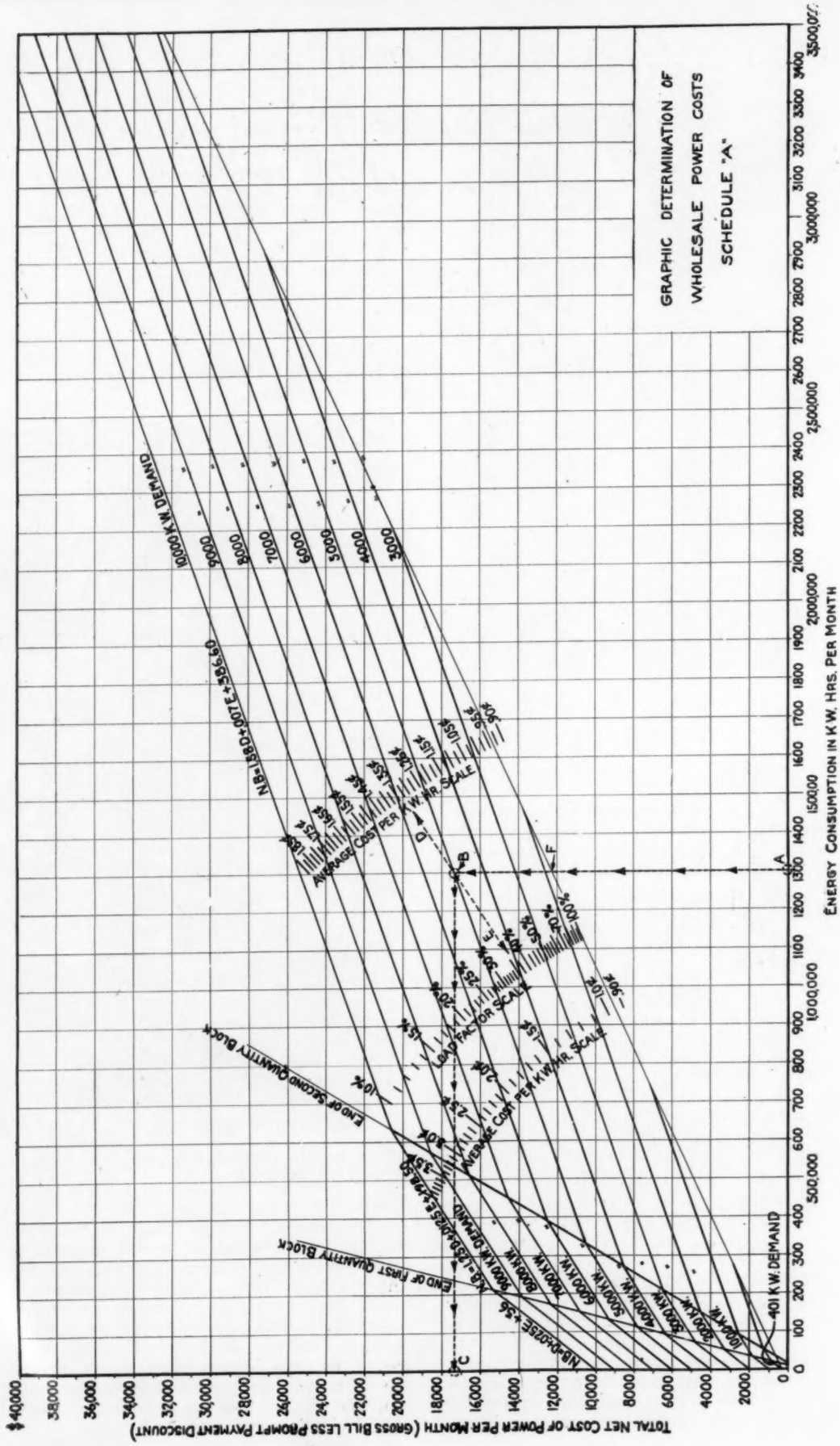
GRAPHIC DETERMINATION OF
WHOLESALE POWER COSTS
SCHEDULE "A"
TOTAL NET COST OF POWER PER MONTH (GROSS BILL LESS PROMPT PAYMENT DISCOUNT)
ENERGY CONSUMPTION IN K.W. HRS. PER MONTH
AVERAGE COST PER K.W.HR. SCALE
LOAD FACTOR SCALE
AVERAGE COST PER K.W.HR. SCALE
END OF FIRST QUANTITY BLOCK
END OF SECOND QUANTITY BLOCK
401 K.W. DEMAND
10000 K.W. DEMAND
9000 " "
8000 " "
7000 " "
6000 " "
5000 " "
4000 " "
3000 " "
NB=.18D+.007E+$66.60
NB=.25D+.025E+$28.50
NB=.02E+.56
A
B
C
D
E
F

FIG. 1.

Discussion of Papers on Inter-Connections between Public Utility and Large Industrials and the Interchange of Power between the two Systems †

By W. B. SKINKLE*

The subject of relations between Public Utility and large Industrials as presented in the three very timely and excellent papers just read is one which is capable of almost infinite expansion, but rather difficult to discuss without going into a mass of detail which time forbids.

All aspects of interconnections, either for the straight purchase of power or for the interchange of power between two systems are so bound up and involved in Industrial economics and in peculiar local conditions, that a contract between the parties must of necessity be very general if the greatest benefits are to accrue to both parties.

In Mr. Schnure's paper, he mentions three conditions under which Public Utility power is commonly purchased; namely, where the Utility furnished all the power; where the Utility furnished only the peak power and where the Utility furnished a base load and the Industrial supplied or controlled its own peaks. The speaker will endeavor to touch on a few of the high spots on this phase of the subject.

Practically all Public Utility schedules for the purchase of firm power are capable of both analytical and graphical solution, and these analyses reveal surprising information on the possibility of cost reduction.

Figure #1 shows a graphical analysis of a typical Public Utility schedule in which the cost of purchased power in Dollars per month is used as the vertical ordinate and the Kw. Hrs. consumed per month as the horizontal ordinate. The family of curves are drawn to show the cost of power for various demands. A bill has been plotted on this chart showing a billing demand of 5,000 Kw. when 1,300,000 Kw. Hrs. of energy are used. Starting at "A", at 1,300,000 Kw. Hrs. on base, move vertically upward until the 5,000 Kw. billing demand line is intersected at "B", then horizontally to the left-hand margin where the bill is seen to be approximately $17,380.00 per month as shown at "C". By following the diagonal lines which radiate from "B", we see that the average cost of energy is 1.34c per Kw. Hr. as shown at "D" and the load factor is 36% as shown at "E". Another very interesting fact uncovered by this graph, is that the consumer really paid approximately $12,300.00 for the power he used as shown at "F", but the difference between the $17,380.00 and the $12,300.00 amounting to $5,080.00 a month is the amount which the consumer penalized himself for his variation from 100% load factor.

While it is well recognized that it would be practically impossible for any Plant to purchase power at 100% load factor, it is surprising how much improvement in load factor can be obtained and what tremendous savings can be made with just a little knowledge of the real meaning of a purchased power contract and just a little co-operation between mill engineers and operators.

The purchase of peak power from a Public Utility Company, by an Industrial, is probably the most uneconomical and undesirable purchase of power which can be made, unless some form of a special contract exists between the user and the Utility. As an example of the cost of peak power, refer to Figure #2. The worst six months in one year's

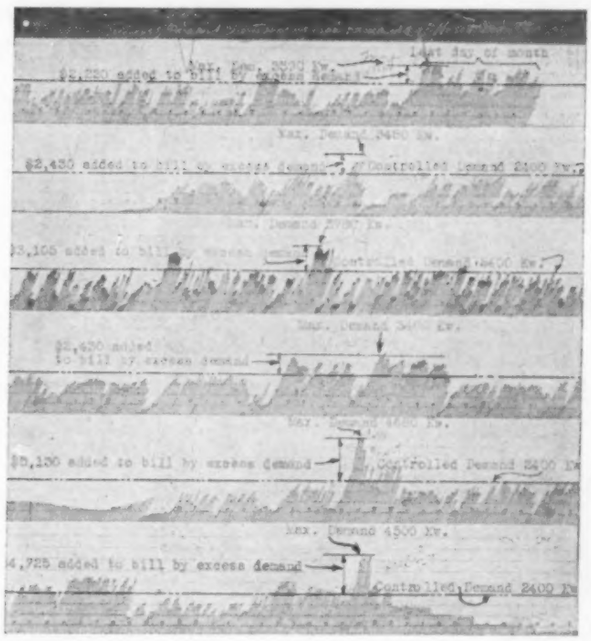

FIG. 2.

operations in the power purchase of a plant were picked out for this case and that portion of the demand chart which set the demand for the month was photographed. The chart tells an interesting story. It is believed that with a proper automatic controlling device, the plant could have operated on a demand of 2400 Kw. which has been called the controlled demand. Take for example, the first line, —the drive for maximum production on the last day of the month, in order to secure maximum shipments in that month, is plainly seen on the demand chart; the increase in the power bill due to the peak-power purchased on that day, amounted to $2,200.00. Note in the second line how a 1½ hour peak added $2,430.00 to the power bill and the third line how a 2¼ hour peak added $3,105.00 to the power bill. In the fourth line, one day added $2,430.00 to the power bill. In the fifth line 6 hours added $5,130 to the power bill and it might be said that the entire amount was added in 1¼ hours. In this case, an

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* Engineer, Pittsburgh District Power Committee, Subsidiary Companies U. S. Steel Corporation.

estimate of the quantity of energy represented by the peak shown above the 2400 Kw. demand line and the cost of this energy was made. It was found that this concern paid for the peak energy above the heavy line, $1.15 per Kw. Hr. Spotty production is shown in the sixth line where $4,725 was added to the demand charge as a result.

Figure 3 shows the results obtained in an industrial plant where the base load was purchased from the Utility company. Through the use of automatic

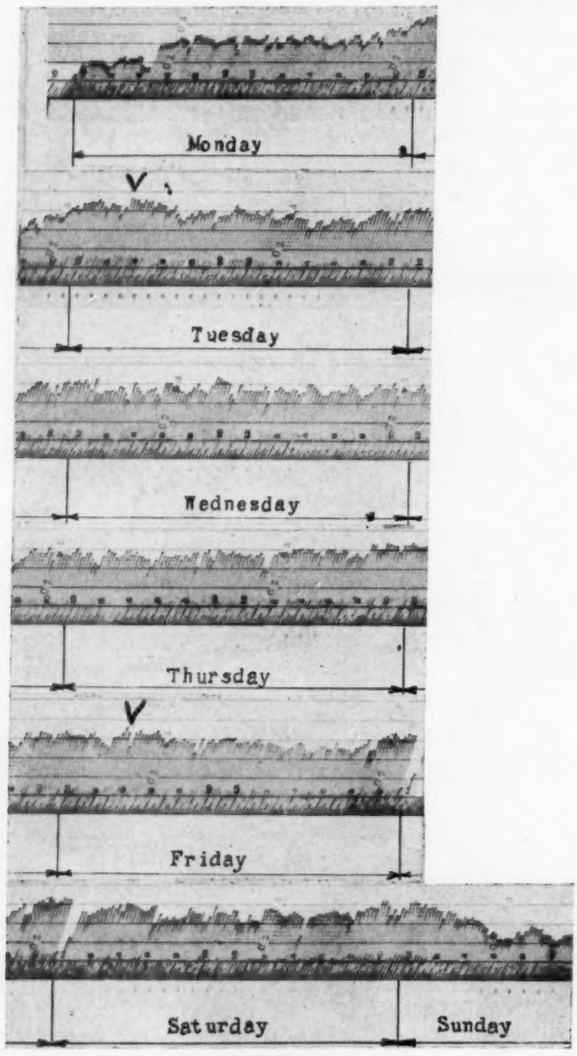


FIG. 3.

control devices, the Industrial carried its own peaks. The difference in the appearance of the demand charts is almost startling. This plant, which is a Steel Works having the usual run of electric motors, has purchased power for a full month at a load factor as high as 95½%, with a resulting cost of energy as low as 7.1 mills per Kw. Hr.

Figure 4 is a small section of a typical demand chart for a steel works and presents an idea of the appearance of a typical unanalyzed, and uncontrolled Industrial load. If the Industrial had no generating equipment of its own, the peaks could be controlled by the temporary suspension of operations on some of their least important equipment or on some of their largest power users. As an interesting example of this kind, a survey of an Industrial having a similar chart was made. One particularly large machine which has short time opeartions similar to rolling of a short bar of steel can be temporarily suspended without loss of production at this plant. The maximum demand recorded during the past year was 6,600 Kw. It was found that by installing automatic devices to suspend operations at this machine the maximum demand could have been reduced to 6,000 Kw., with the result that average interruptions on this one machine amounting to 1 minute per month could have cut the power bill $4,600.00 per year. Going further, and reducing maximum allowable demand to 5,400 Kw., the average interruptions would have totalled 20 minutes per month with a resulting saving of $14,000.00 per year in the cost of power. Carrying the application of the load control device still further and placing the allowable maximum demand of 4,800 Kw., interruptions on this one machine would have amounted to 3-1/3 hrs. per month, with a resulting saving of $28,000.00 per year in the cost of purchased power. 3-1/3 hrs. a month represents less than ¾ of 1% of the operating hours.

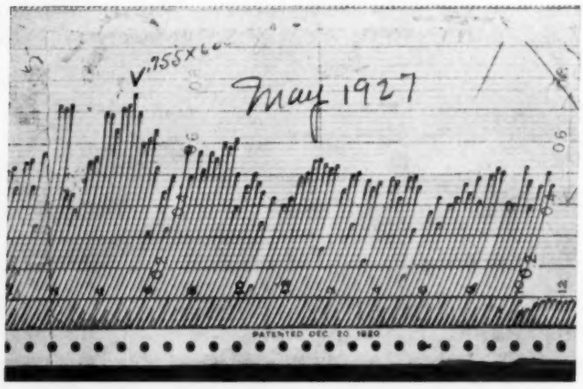


FIG. 4.

This is a rather sketchy review of the possibility of economic analyses where interconnections between Utility and Industrials are used exclusively for the purchasing of power from the Utility Company. The speaker covered this subject in detail in a paper presented in 1929 before the Engineers Society of Western Pennsylvania. (Purchasing Public Utility Power for Industrial Use. E. S. W. Pa. Vol. 49—Jan. 1929).

Interconnections between Public Utilities and large Industrials offer by far the greatest economies to both parties through interchange of power. Such agreements are only possible where the Industrial has large quantities of either by-product, or very low-priced fuel, available in such form that it is not economical to store. Two such installations have been described and one or two others have been mentioned by the authors in their papers. The possibilities of inter-change between Utilities and Industrials opens up a vast field of industrial economies which, owing to the almost unlimited number of special conditions which may exist at every point of interchange, and to the fact that these special conditions may change radically from hour to hour and month to month, present a tremendous handicap to the drafting of sufficiently flexible agreements which will meet these constantly changing conditions. One

essential feature is necessary for the successful operation of **any** interchange agreement and that is that both sides **must** benefit financially from such an agreement, otherwise the agreement will be terminated at the earliest possible time by the party not benefiting to the full extent. The speaker is of the opinion that in order to have interchange of power operating in a manner which will be of maximum benefit to all parties concerned, this interchange should be **unrestricted,** i.e.—the agreement should be sufficiently flexible so that the Industrial can draw power from the Utility at any time it desires and can also deliver power to the Utility whenever a surplus of low price fuel is available.

It naturally follows, therefore, that the prices for the various kinds of power interchanged should be fixed at such a rate that any kind of power can be profitably sold by one party and purchased and absorbed by the system of the other party.

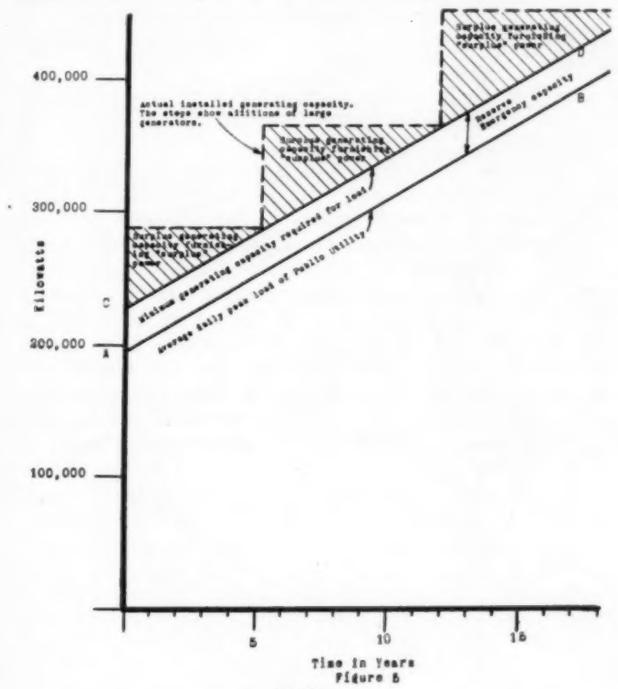


FIG. 5.

Analyses of the interchange problem, shows that five different kinds of power can pass between a Utility and an Industrial. They are:

1. Firm power sold by the Utility at any time and in any quantity up to the limits of either the equipment or the contract.
2. Surplus power available from either system by reason of surplus generating capacity idle and awaiting growth of the system on which it is installed.

3-4 Dump power which may be either "On Peak" or "Off Peak". This is power available in the Industrial system by reason of surplus by-product heat which it is not practical or economical to store and hold in reserve.

5. Lastly and most important is emergency power available from either system to the other on short notice in case of a sudden and unforseen emergency.

All these different classes of power have radically different costs to the producer and radically different values to the purchaser. These various kinds of power and their values are shown graphically in Figures 5 and 6.

In both of these figures, the vertical ordinate is Kilowatts and the horizontal ordinate is time in years.

The line AB of Figure 5 represents the constantly increasing daily peak loads during the normal growth of a Public Utility system.

The generating capacity of this system must be sufficient to carry this load, and in addition, it must have sufficient reserve capacity to replace any regularly operating unit that must be taken off the line for any reason.

Generating capacity must be added to the system in comparatively large units in order to take advantage of the better economy of the larger sized units.

A system developing independently with no connection with its neighboring systems could plot its growth as shown in Figure 5, which shows the actual generating capacity added in large blocks to the upper line CD.

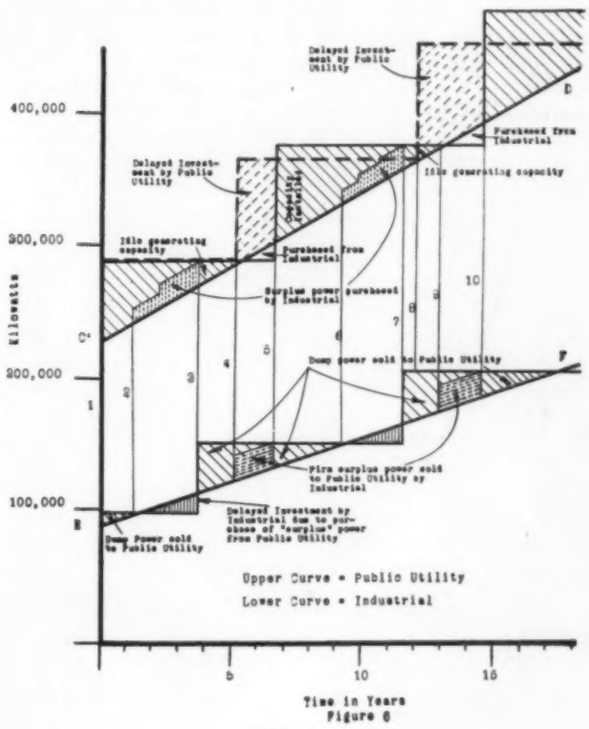


FIG. 6.

The capacity as shown by the vertical distance between the line CD and the dotted lines represents "Surplus Capacity" held idle in reserve waiting for system growth. The investment in this capacity must be made **in advance** of the requirements of the system for **any part of its output,** and the fixed charges on this investment must be absorbed by the system as a whole.

When two neighboring systems make an interconnection for the purpose of interchanging energy and sharing the beneficial results of this interchange, the combined operation can best be explained with the aid of Figure 6 in which the co-ordinates are again Kilowatts and Time. The upper curve repre-

sents the operations of the Utility and the lower curve the interconnected Industrial.

The sloping line CD of the upper figure represents the minimum safe generating capacity as in Figure 5.

Superimposed on the upper line CD in dotted lines is the normal additions in generating capacity that are shown in Figure 5. The sloping line EF of the lower figure shows the same values for the Industrial. A hypothetical set of additions in generating capacity to the Industrial system are shown in steps on this line.

At the beginning of the operations of the interchange agreement, both companies have Power from surplus generating capacity to sell. Because the Utility does not **need** additional energy, the Industrial takes advantage of clauses permitting the sale of low priced dump energy and delivers this kind of energy to the Utility. This condition continues over the interval from 1 to 2. At 2, the Industrial load has grown to a point that additional reserve is needed, but owing to the fact that the reserve required is small, it becomes more economical to arrange for this reserve with the Utility and by so doing delay the investment in additional generating capacity until such time as a definite load for this reserve unit has been developed. Because of "Minimum clauses," probable in such a contract, an actual purchase up to the amount of the minimum takes place and the Industrial buys a small amount of power, thereby shutting down its most inefficient unit.

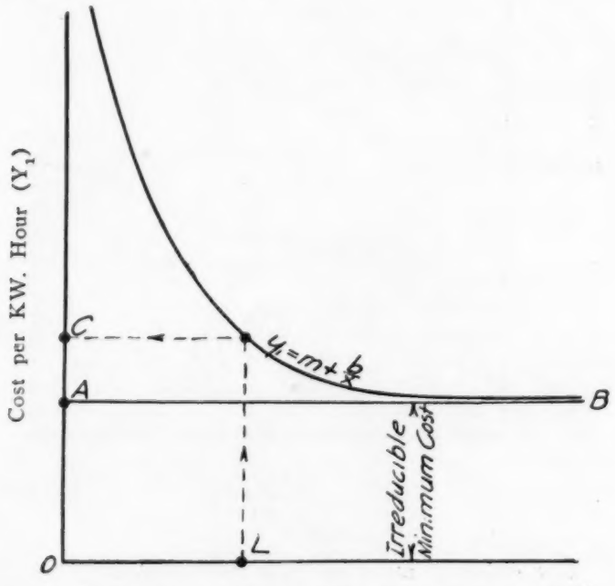


FIG. 7.

As time passes from 2 to 3, the quantity of purchased energy increases and the quantity of "Utility reserve" decreases until it is used up by the growth of the Utility System. At an agreed time, before point 3 is reached, which should be sufficient to permit the Industrial to install additional capacity, the Utility notifies the Industrial that the load must be dropped on a certain date. The Industrial is thus given time to install generators to replace the purchased energy. Because of the economy of large units, the Industrial installs more capacity than is immediately required and when point 3 is reached, both companies again have surplus generating capacity which neither wants from the other, and as a result the Industrial again takes advantage of the low priced dump energy clauses, and at least earns fixed charges on its investment in surplus generating capacity which would otherwise be idle and nonproductive between points 3 and 4. At 4, the Utility has used up its reserve and is in the market for surplus capacity which can be furnished by the Industrial until such time as point 5 is reached, at which time the Utility must have additional capacity ready to operate. These cycles may be repeated indefinitely.

Figure 6 indicates that during periods 1 to 2; 3 to 4; 5 to 6; 7 to 9 and beyond point 10, the Industrial dumps power. The Industrial furnishes the Utility with firm surplus power during periods 4 to 5 and 9 to 10 and has purchased power during periods 2 to 3 and 6 to 7. It has also built up at least a partial load for its generators previous to their installation.

The Utility has sold some power from equipment that would otherwise be idle and in this manner has helped to carry the fixed charges on this otherwise idle equipment and has also been able to delay the large investments in their units for periods of time represented by 4 to 5 and 8 to 10. These delayed investments make possible large savings to both parties. A Utility investment in additional power house may easily reach six million dollars, which if delayed for one year means a saving of $780,000 in fixed charges. A large Industrial may easily spend two million dollars, the fixed charges on which will amount to $260,000 a year, and they can probably be delayed for a much longer time than the Utility investments as a result of the interconnection.

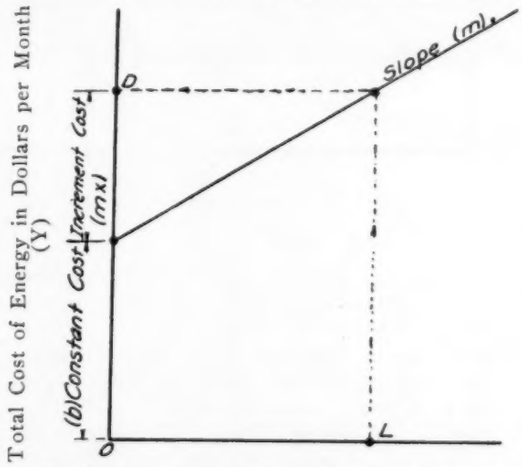

Total Cost of Energy in Dollars per Month (Y)
Slope (m)
(b) Constant Cost
Increment Cost (mx)
0
L
Production of Energy in KW. Hours per Month (X)

FIG. 8.

The next consideration is that of the cost and value of the various kinds of power which may be interchanged. These have a very wide variation if a true economic study of their costs is made. For this reason, I will ask your indulgence while I review a small portion of a paper (Discussion of Elements Entering Into the Cost of Producing Power, A. I. & S. E. E., June, 1928) which I presented before the Iron and Steel Engineers in Chicago in

1928. Figure 7 shows the cost of power per Kw. Hr. and is a standard, well recognized figure showing how, with increased production, the unit cost of power constantly decreases and approaches an irreducible minimum. A curve of this type exactly fits the definition of an hyperbola and if expanded will show that the total cost of operating a power plant at various loads will become a figure similar to Figure 8, wherein the total cost of power may be divided into two parts, namely, a constant cost which is independent of the load and an increment cost which is directly proportional to the load. An actual

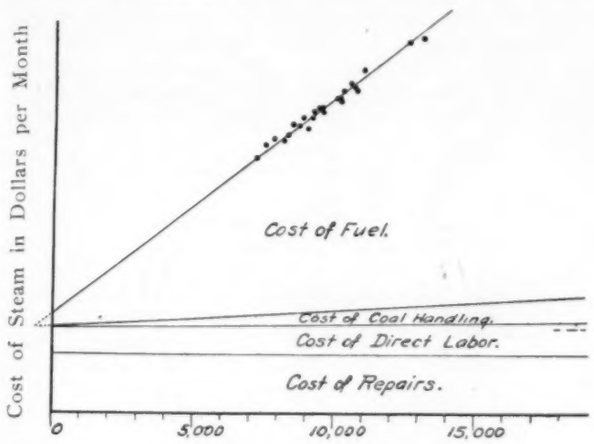


FIG. 9.

application of this principle to a boiler house is shown in Figure 9. The actual costs as taken from the cost sheets were corrected to a common base fuel price and the erratic variation caused by gradually accumulating repairs, which were made at widely separated intervals of time, were funded and a proportional amount of this fund charged to each month. The points representing 24 consecutive months operation at widely varying loads seem to prove the soundness of the original assumptions. A number of similar analyses have been made during the past three or four years and they have "proven out" even better than this example.

Figure 10 is an extension of this same assumption carried to the cost of power from a 15,000 Kw. turbo generator. Note the large part of the costs which is represented by fixed charges and also the very large part of the costs which are constant regardless of the load on the unit. The curved portion of the upper line GH shows the decreasing thermal efficiency of the unit (particularly the boilers) as the unit becomes overloaded.

Now let us consider how costs change for the various kinds of power which can be interchanged.

There can be little question but that the cost of firm power is represented by the vertical distance between the base line and the line GH.

Surplus power from units already installed, but held in reserve and which must be started up for supplying the surplus power, will increase the costs of operation long the line GH, but will omit the fixed charges which are already being absorbed by the system.

Surplus power from a unit already in operation at partial load will only increase the costs by an amount equal to the slope of the line GH.

In the case of Dump Power generated by units already in operation from surplus fuel which, if not converted into power, must be dissipated at its source, the existing costs will change only by an amount equal to the slope of the straight line JK.

In this case, the fixed charges are already being absorbed by the system. The constant operating costs are already being absorbed by the load for

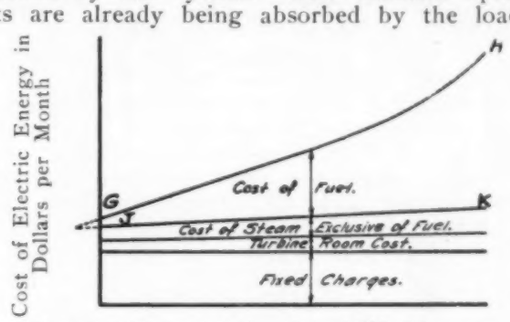


FIG. 10.

which the unit is regularly operating. If no regular use can be found for the surplus fuel immediately available, its value to the Industrial is zero. The only part of the costs which do increase are a very small part of the repairs due to the increased load, a little of the water treating costs for additional steam and a little additional condenser water.

It is the opinion of the speaker, which is formed after careful analysis of a number of units, that for the average turbo generator of 15,000 Kw. capacity, the **increase** in cost to the industrial for power dumped on the Utility will be in the neighborhood of 4/10 of one mill per Kw. Hr. Such a small added cost offers a sufficient spread between it and a Utility Company cost as represented by their increment plus line losses to the point of interchange, so that there are possibilities of permitting an unrestricted dumping of power to the profit of both parties to the agreement.

ASSOCIATION OF IRON & STEEL ELECTRICAL ENGINEERS

CONVENTION AND IRON AND STEEL EXPOSITION

CLEVELAND AUDITORIUM **CLEVELAND, OHIO**

JUNE 15-16-17-18-19, 1931

The Coreless Induction Furnace in the Steel Industry†

By E. F. NORTHRUP*

Heat from a current carrying resistance, heat from and arc and heat inductively produced constitute the three and, practically considered, the only means of obtaining useful heat by a conversion of electric energy. The general features of these three means of obtaining useful heat are familiar to all who have given thought to electric heating. Even the latest methods of inductive heating are quite generally known and are rather widely understood. I shall, therefore, avoid text book explanations and shall touch only on certain aspects of "coreless inductive" heating by means of high frequency current which seem to me should have particular interest in the iron and steel industry.

When electric energy is turned wholly into heat, there is a certain proportion of the heat developed which is wasted, in the sense that it is not used for the end intended. The efficiency of any process whereby electric energy is converted into heat is the ratio of the utilized heat to the total heat equivalent of the energy converted. This statement appears self evident and scarcely worth making. It is, nevertheless, important. The electrical efficiency of any type of electric heater may be high, but the electric heater may have low useful value because the heat efficiently produced is only in small part utilized for the end intended. A case in point would be where a large electric furnace of great efficiency in producing heat in a mass is extremely inefficient for melting metal because the power applied to the furnace is chosen little more than the equivalent power of the heat which escapes when the metal is near its melting temperature. By merely applying more power to this same furnace, it becomes transformed from an inefficient melting device into a very efficient one. Again, we would call an electric heater for a small room very efficient as a heater of the air in the room when the doors and windows are closed and a very inefficient heater when these are open.

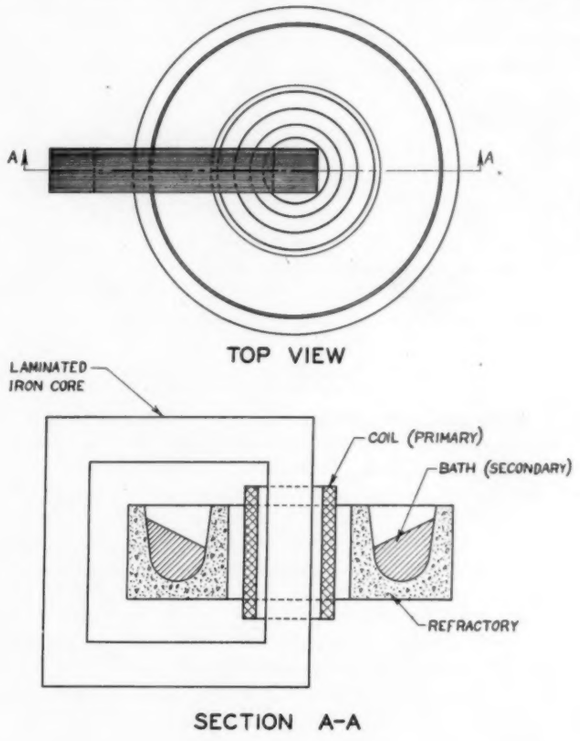
The process of the conversion of electric energy into useful heat should be, however, much more than merely efficient, if scientific and commercial requirements are to be fulfilled. The electric process should be extensive enough to give:

a. Any degree of temperature desired.
b. Uniformity of maximum temperature throughout the mass heated.
c. A supply of calories to the product heated unmixed with contaminating matter.

The electric heating process should be of a nature which permits the economical conversion of any desired amount of electric power into useful heat. In other words, the commercial world wants to heat tons, though the scientist may be satisfied with ounces.

If we exclude the method of causing heat to enter a body by focusing upon it radiant energy such as sunlight, then only by inductive electric heating is it possible to secure the above ends just stated.

Inductive electric heating is more versatile in application than any other electric method of heating. It has been proved by theory and demonstrated in practice that where melting processes are involved, it is superior to any other known method for the direct conversion of electric energy into useful heat.



KJELLIN OR RING TYPE INDUCTION FURNACE

FIG. 1—Cross Section of Ring Type Induction Furnace.

When a body is heated inductively, the heating device is a transformer in which the inductor is the primary, usually of many convolutions, and the body heated is the secondary; almost always to be considered as a single turn secondary.

In order to save words in describing or referring to the two elements of an inductive heater, I shall always call the primary or inducing coil the "inductor" and shall use the word "susceptor" to signify the secondary or body heated. The word "susceptor" was suggested by Mr. Theodore Kennedy of our company, and I think it is useful.

When current flows through an inductor, there is associated with the inductor a certain definite number of lines of magnetic induction. A certain proportion

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* Vice President and Technical Adviser, Ajax Electrothermic Corporation, Trenton, N. J.

of these lines will thread or pass through the susceptor. When one has in mind an ordinary transformer, the primary and secondary windings are wire and hence linear in character. In this case the usual language applies which states that all or part of the lines of induction, supplied by the primary winding, interlink with the secondary winding. In an inductive heater, the susceptor is frequently not linear in character but consists of a mass, usually of cylindrical form. In this case, lines of induction developed by the inductor cannot be said to interlink with the susceptor nor even to thread through the entire area of any chosen cross-section of the susceptor. However, for engineering purposes, we can say that of the total number of lines supplied by the inductor, there are a certain number of these lines that thread through some portion of the susceptor; and we can call the ratio of the number of such lines to the total number of lines supplied by the inductor, the "coupling" factor. If this ratio is high, the coupling is said to be close; if low, the coupling is loose. In practical cases that arise with most types of inductive heaters, the precise value of the coupling factor is difficult and often impossible to calculate; but by combining approximate calculations with empirical data, the closeness of coupling may be determined with a precision sufficient to meet engineering needs. With this conception of coupling in mind, it can be stated as a generality that the electrical efficiency of any inductive heater or furnace will increase as the closeness of the coupling improves.

In radio transmission, the coupling between sender (the inductor) and receiver (the susceptor) is exceedingly small, and the proportion of energy picked up of that radiated is almost infinitesimal; but here the end sought is to flash thoughts through space, not to transmit and convert electric energy. This

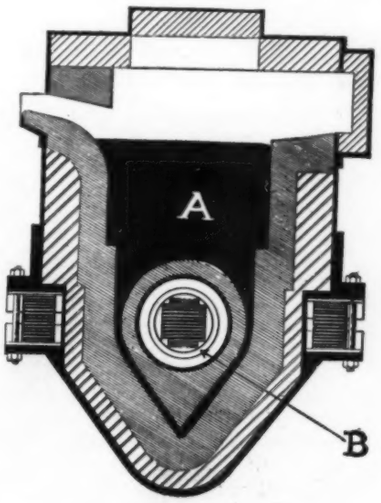


FIG. 2—Cross Section of Ajax-Wyatt Furnace.

last is the very essence and purpose of all inductive heating. If the coupling is close, it is made so to secure an efficient transmission of energy from inductor to susceptor. To secure this closeness of coupling in an electric induction furnace, engineers first adopted the same means as the designers of transformers use. They made the susceptor in the form of a generally circular channel, horizontally disposed and capable of holding a ring of molten metal. Through this ring of refractory, they passed transformer iron which was made to interlink with a susceptor formed also into a closed loop. On some part of the closed iron loop, the primary or inductor was wound. By this arrangement, the greater part of the lines of magnetic induction set up in the iron by the inductor are carried by the highly permeable transformer iron through the susceptor. Thus the coupling factor was made fairly good—not good enough, however, to secure a satisfactory power factor when the furnace assumed a large size.

Fig. 1 shows the essentials of this earliest type of so-called horizontal ring type induction furnace, due I believe to Colby, of Baker and Company, Newark, N. J.

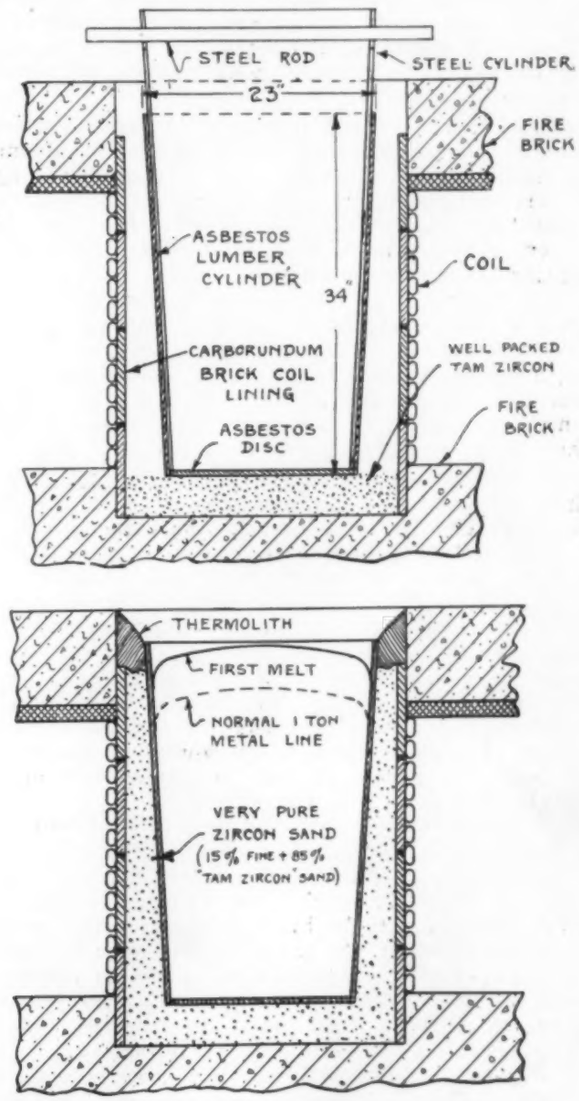


FIG. 3—Cross Section of Ajax-Northrup Furnace.

Inductive heaters of this type have been limited almost entirely to the melting of metals of the ferrous group. When used with non-ferrous metals, the so-called pinch effect (first observed in a furnace and described as a furnace phenomenon by the late

Dr. Carl Hering) is so marked that the furnace becomes impracticable. The closeness of coupling can be preserved by using transformer iron, and the breaking of the molten metal circuit can be avoided and other highly desirable features secured by making the molten metal lie in a V or U shaped channel or tube of refractory which is disposed in a vertical plane. The ends of the channel, called the "resistor" open into the base of a pool of molten metal called the "bath" which completes the electric circuit of the secondary or susceptor, as we have called it. This type of "cored" (transformer iron passed through the primary and secondary) induction furnace, known as the Ajax-Wyatt furnace, is shown in Fig. 2. It owes its development to Mr. G. H. Clamer who financed it and contributed much to the technical features and to Mr. James Wyatt, his technical assistant.

In the non-ferrous metal melting field, it has no rival for continuous melting; and many hundreds of successfully operated furnaces are in use throughout the world. It is powered with current of normal frequency.

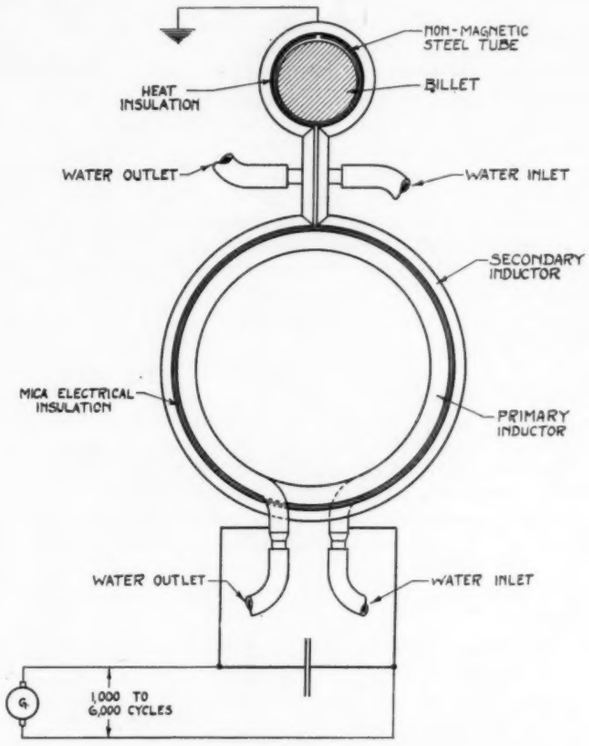
Lastly we have the system of inductive heating, generally using specially provided high frequency current, in which the susceptor is a mass through which **no transformer iron passes.** It is therefore called the coreless inductive system of heating. This system may be applied to intermittent heating or melting or to continuous operations. It is applicable to the melting of all metals, and in many cases may be used, with the aid of specially applied "energy absorbers" to the melting of electrically non-conducting materials as quartz, glass, etc. Its field of application is also in the heating, short of the melting temperature, of rods, large pipes, tubes, billets, sheet steel, etc.

To make more clear the remarks that follow, there is shown in Fig. 3 a schematic drawing of the primary **essentials of a coreless inductive** heater.

These consist of (a) an inductor of relatively few turns wound in **one** layer, (b) provision for artificially cooling the inductor—usually made hollow so water may circulate through the same winding that carries the inducing current, (c) a susceptor, which is sufficiently electrically conducting so that the electric-wave-energy supplied by the inductor may be absorbed by the susceptor and become converted into useful heat, (d) a source of alternating or oscillating electric current, usually of a frequency higher than service lines supply.

The inductor is placed as near the susceptor as conditions will permit in order to secure as close a coupling as possible. It is evident that the coupling can be made much closer when materials, as steel billets, are to be heated without being melted, than when metals, etc. are to be melted in a crucible or chamber which must not allow molten matter to escape. In the latter case, a certain space between inductor and susceptor must be reserved for the crucible wall and heat insulating refractory.

Fig. 4 is a cross-sectional view of an inductor for heating billets to forging temperature. The latter employs a secondary coil which steps the voltage applied to the inductor down to a few volts. In this case, the coupling between secondary inductor and the susceptor—the billet to be heated—may be as close as physical clearance will permit. The heater shown in Fig. 4 heats a billet to forging temperature in two minutes, the billet being 2¾" in diameter and 5" long. The efficiency of the arrangement becomes greater as the frequency chosen is higher. For 2000 cycles, the kw., delivered to inductor, required to heat uniformly in two minutes to about 1200° C. is 82 kilowatts.



FOCUS INDUCTOR AS APPLIED TO BILLET HEATING

FIG. 4—Line Drawing of Billet Heater.

Since the coupling of a coreless inductive heater is generally, of necessity, loose, it might be supposed that its efficiency would be low. This, however, is not true, which may be explained as follows: For purposes of engineering precision, we can say that the rate of energy transferred from inductor to susceptor is expressible by the relation

$$H \propto CN\,(ni)^2$$

where C is the coupling factor, N the frequency used and $(ni)^2$ the square of the ampere turns of the inductor. It thus appears that by choice of a sufficiently high frequency, we can make the coupling C fairly loose, and still transfer energy from inductor to susceptor without much loss of rate of heat transfer and, an analysis shows, without too much sacrificing efficiency of heating. When once it is recognized that with a proper choice of frequency, we obtain very good efficiency of heating without any transformer iron interlinking the susceptor, it is seen that a very wide field is open for **coreless** inductive heating. When metals are to be melted, the metal-holding chamber may take the form of a crucible, while rods, billets, steel rolls, etc., may be effectively heated by induction without the use of a cru-

cible, merely by passing them through the inductor coil.

It can be shown by analysis, that a step-up or step-down transformer which makes no use of iron, can be designed to be highly efficient provided the frequency used is of the order of 1000 to 6,000 cycles.

When small diameter billets or metal tubes are to be heated by passing them through an inductor coil, the coupling between inductor and susceptor would be loose, necessarily, if any considerable amount of electrical or heat-insulating material were required for the space between inductor and susceptor. Such material is necessary when the high voltage needed is applied to the inductor terminals. By resorting to the air core transformer arrangement shown in the figure, in which the high voltage for the primary inductor is stepped down by a secondary inductor which in turn acts directly on the susceptor, as rod, tube or billet, the coupling between the secondary inductor and susceptor may be made as close as physical clearance will permit. This close coupling between secondary inductor and susceptor brings up the efficiency and increases the power factor of the supply line. It likewise makes it feasible to fit tightly in the secondary inductor a non-magnetic steel tube (split at one place lengthwise) through which a susceptor can be passed smoothly and without abrasion. When holding the hand on this secondary inductor, with a white hot uniformly heated billet inside, no voltage or temperature can be felt. The device is, therefore, rugged, safe and efficient and has a much higher power factor than a melting furnace which of necessity must have a loose coupling.

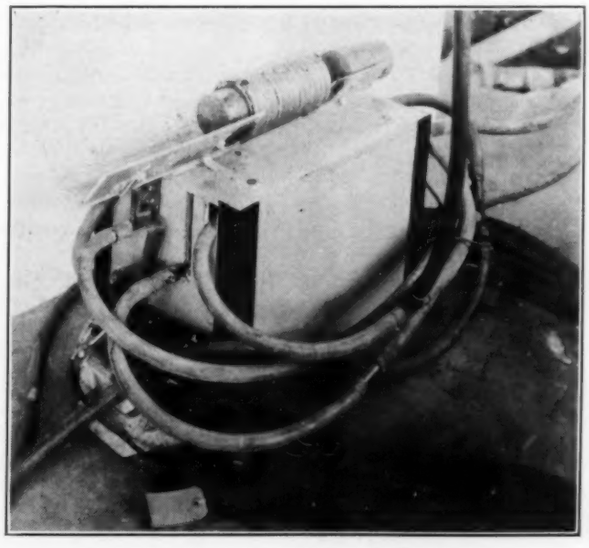


FIG. 5—General View of Billet Heater.

It has been stated by certain electrical manufacturing companies that they are prepared to supply high frequency generators of the inductor type at prices which are not prohibitive, which will supply current, if needed, at a frequency of 6,000 cycles. For stock of 2″ to 4″ in diameter only 6,000 to 2,000 cycles would be required and quotations for 400 kw. machines giving a frequency in this range have been prepared.

These developments, I believe, will open up, in the near future, an extensive use of coreless inductive heating of metals, especially ferrous metals, which are to be brought to an annealing or to a forging temperature. No commercial use of the method just described has been made, but there are good prospects for this phase of inductive heating. Numerous experiments and shop tests on billet, tube, pipe and roll heating have been made, which have demonstrated beyond doubt the great technical merits of the method. The economics and other advantages in production on a commercial scale have yet to be determined. The simple methods employed for correcting the power factor of the heater with dependable static condensers in order that the generator shall furnish the power component only of the kv-a. employed have been so often described in full that I shall not repeat them here. However, I have shown in figures 4 and 7 the essentials of the electric circuits used in billet heating.

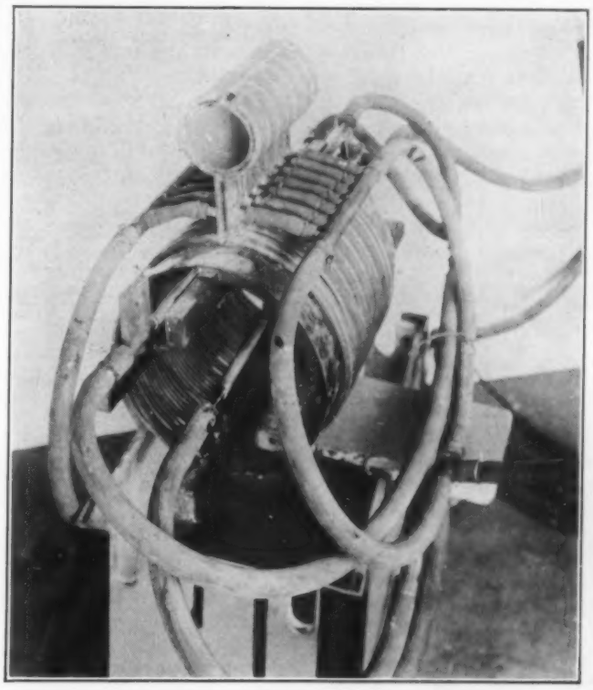


FIG. 6—Detail View of Billet Heater.

It may be mentioned that in the type of heater just described, the power factor at the generator terminals changes very little when the billet gradually looses magnetism with increasing temperature. The change in power factor is only about 7% when the billet is put in or removed. Hence, no provision need be made for putting condenser units in or out of circuit. After the first adjustment, they are not changed again. By maintaining the generator voltage constant with a voltage regulator, and with the same power supplied to each billet heated (if all are of same size and weight) we have the happy result that the temperature of every billet heated is exactly the same, provided all are in the heater the same time. All pyrometric measurements are discarded.

A solid billet or a steel roll begins to heat on the outside first. The ring of high temperature creeps in toward the axis until the entire billet is uniformly heated, if desired. If it is required to heat the out-

side surface of a steel roll to a quenching temperature to make this surface very hard and have its successive annuli as the axis is approached of lower and lower temperature, this is easily arranged by regulating the speed of heating.

The limits of this paper do not permit me to more than mention the fact that inductive heating may be applied now technically, and probably in the near future economically, to such applications as: the heating to forging temperatures of most symmetrically shaped ferrous metal bodies; to a proper annealing temperature of stacked steel-sheet of the type used in automobile bodies; to the heating for annealing purposes of continuously travelling metal strip, small tubes, rods, etc.; to maintaining the temperature in steel billets after removal from the molds, etc. The advancement, however, to a place where the methods are available to industry, can come only by co-operation and vision of capitalists, metallurgists, electrical experts in the high frequency field and of large electrical manufacturing companies.

Thus far the commercial use of inductive heating has been chiefly confined to melting of metals. For this purpose, there is now available, and for the most part in use, about twenty-five thousand kilowatts of high frequency power for coreless induction furnaces and about 50,000 kilowatts capacity of the Ajax-Wyatt type.

Some typical coreless induction furnaces are shown in the figures, and are described below.

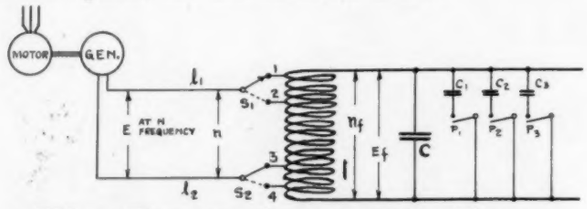


FIG. 7—Elementary Generator Wiring Diagram.

In Fig. 7 is shown the elementary wiring diagram of a coreless induction furnace circuit. The furnace is supplied, usually from a motor generator or frequency changer set, and capacitors are used to correct the power factor of the circuit to unity.

The type of motor generator set usually used for most steel melting installations, consists of an 800 volt, 960 cycle alternator, driven by a three phase induction or synchronous motor. The exciter for the generator field is mounted on the same shaft as the generator.

Figure 8 shows the furnace proper. While certain changes have been made in the top part, the tilting device and trunnions are as shown. It may be seen that the furnace turns about its approximate center of gravity until ready to pour. When in the pouring position, it turns through upper trunnions, so arranged that the center of the pouring stream will remain stationary. This obviates the necessity of moving the mold during pouring operations. A furnace of this design of 4500 pounds capacity has been made in this country and has been recently operated at the Watertown Arsenal, Watertown, Mass.

A battery of 600 lb. furnaces installed in the Bethlehem plant of the Bethlehem Steel Company have been the subject of much favorable comment in recent discussions of steel and steel making, and are used chiefly for tool and special alloy steels.

The purchase of additional melting equipment shows that the Firth-Sterling Steel Company is getting satisfactory results in tool and stainless steel melting.

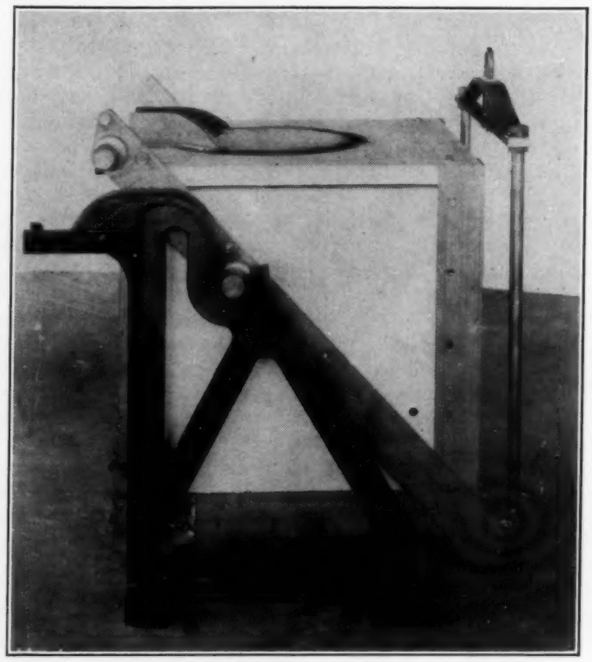


FIG. 8—1000 lb. Tilting Furnace on Trunnions.

The Hoskins Manufacturing Company at Detroit are obtaining excellent results in nickel-chromium alloy melting. They also have increased their melting capacity.

Homogeneity of successive melts is one of the outstanding advantages of this equipment. The furnace is poured empty each time, thus leaving no heel in the furnace.

At the time of their installation, the two, one ton furnaces at the U. S. Cast Iron Pipe and Foundry Company, Burlington, N. J., were the largest furnaces of their type in the United States. They are used for super-heating cast iron and melting steel. Furnaces of 3½ ton capacity are being made to be powered with 1200 kilowatts.

In an installation of comparatively recent date at the plant of the Lebanon Steel Company, Lebanon, Pa, the coreless induction furnaces are used mainly for the production of stainless and alloy steel castings.

In the installations at the Duriron Company, Dayton, Ohio, in their larger installation stainless and miscellaneous alloy castings are made; while in the smaller size experimental alloy work is carried on while the two size units may be operated from the same generator source, many companies prefer the smaller spark gap type of converter equipment for auxiliary or laboratory work. The Duriron Company, like many other companies, uses the smaller type of equipment as a pilot.

Just a few of the typical and representative installations have been briefly set down. Before concluding my paper, I might summarize the lines of development toward which we are working. The lines of commercial development of coreless inductive

heating which appear likely, may be listed as follows:

1. More and larger ferrous metal-melting furnaces with the gradual displacement of arc furnace melting.
2. Heating to forging temperature of symmetrically shaped ferrous metal bodies in increasing quantities, and the maintaining of temperature in hot steel billets as pushed from the molds, to replace the present soaking pits.
3. Heating to an annealing temperature stacked piles of thin sheet steel which is for use in automobile bodies.
4. Heating for annealing purposes or normallizing continuously moving metal strip and rod.
5. Heating with temperature control and great uniformity very large muffle annealing furnaces. In this case, the energy absorber in the furnace would consist of ferrous alloy non-corrodible castings.
6. Extension of inductive heating with small furnaces supplied with very high frequency power for all varieties of scientific investigation where freedom from contamination of the charge is essential and where the temperatures that may be reached will meet all scientific requirements.
7. The production on a large scale of very high temperature heaters for such purposes as the graphitization of coke.
8. The construction and use of multiple ton furnace-ladles which will not only maintain the metal at a constant temperature but in addition, electrically stir this metal to any desired degree for refining it under slags.

No uses of inductive heating have been mentioned above that have not been tested out in practical trials and are therefore known to be sound technically.

Rolling Mill Lubrication†

Effect of Various Lubricants on Power Consumption

By E. S. GLAUCH*

SECTION 1—Resume of recent changes in Rolling Mill Lubrication.

SECTION 2—Description of Special Testing Machine with curves showing results of some of tests made on same.

SECTION 3—Results of Tests made in rolling mills, showing possible savings in power by using proper Lubricant on Roll Neck Bearings.

SECTION 1

Lubrication in Rolling Mills has changed considerably in recent years. Several reasons may be responsible, one of which is high speeds which have been brought on by continual demand for increased tonnages and lower costs. Another reason may be given as the improved design of new equipment to which some thought had been given as to how proper lubrication was to be obtained. Still another reason may be given, that is, the rapid change to electric or motor drive.

The anti-friction bearings can also be credited for increased interest and improvement in lubrication. Bearings of this type have very forcibly brought to everyone's attention, high frictional losses sometimes encountered in rolling mill equipment.

The electrification of equipment has made it possible to readily check power consumption and the benefits that might be derived from changes in lubrication.

In the early types of mills were found gears and pinions that were not enclosed so as to be bath lubricated.

This, resulted in gear and pinion greases with asphaltum bases and in some cases even tar has been used. This type of grease, if you can call it a grease, provided a protective coating for the teeth. Along with protection, however, goes high frictional losses due to internal friction within the lubricant.

Changes in design brought enclosures whereby a more fluid gear lubricant could be used. Some of the latest pinions stands and gear reducers are lubricated by an oil which is circulated after use to a filter, then back to gears or bearings. On units of this type the oil is usually sprayed on the teeth at point of contact.

In some cases, where this system has been used, slightly increased wear has been noted on the teeth, but not enough to offset the benefits derived from lower frictional losses and improved operation.

Table gears are also being enclosed so that it is not necessary to use as heavy or tacky a lubricant as with the open type. Bearings for tables have also been improved and, of course, the anti-friction type bearing is rapidly finding new uses in the various mill equipment.

Until a few years ago, the method of lubricating the roll necks had been practically unchanged. At one time, suet or often-called tallow was the principal roll neck lubricant. Suet had certain advantages when compared with greases. The principal advantage was it would stay against the neck better than earlier greases.

Greases, as made for this service in recent years, have replaced suet in most mills. Block Greases have been found to give better results in some cases than the bulk greases.

This may be due to the grease itself or, in some cases, due to being easier to apply, the mill men would give more attention to its application.

Tests, the results of which will be mentioned later, show that different greases, even though applied in the same manner, will greatly effect power consumption.

† Presented before A. I. & S. E. E., Chicago Section, February 10, 1931.

* Mechanical Engineer, Joseph Dixon Crucible Company, Jersey City, N. J.

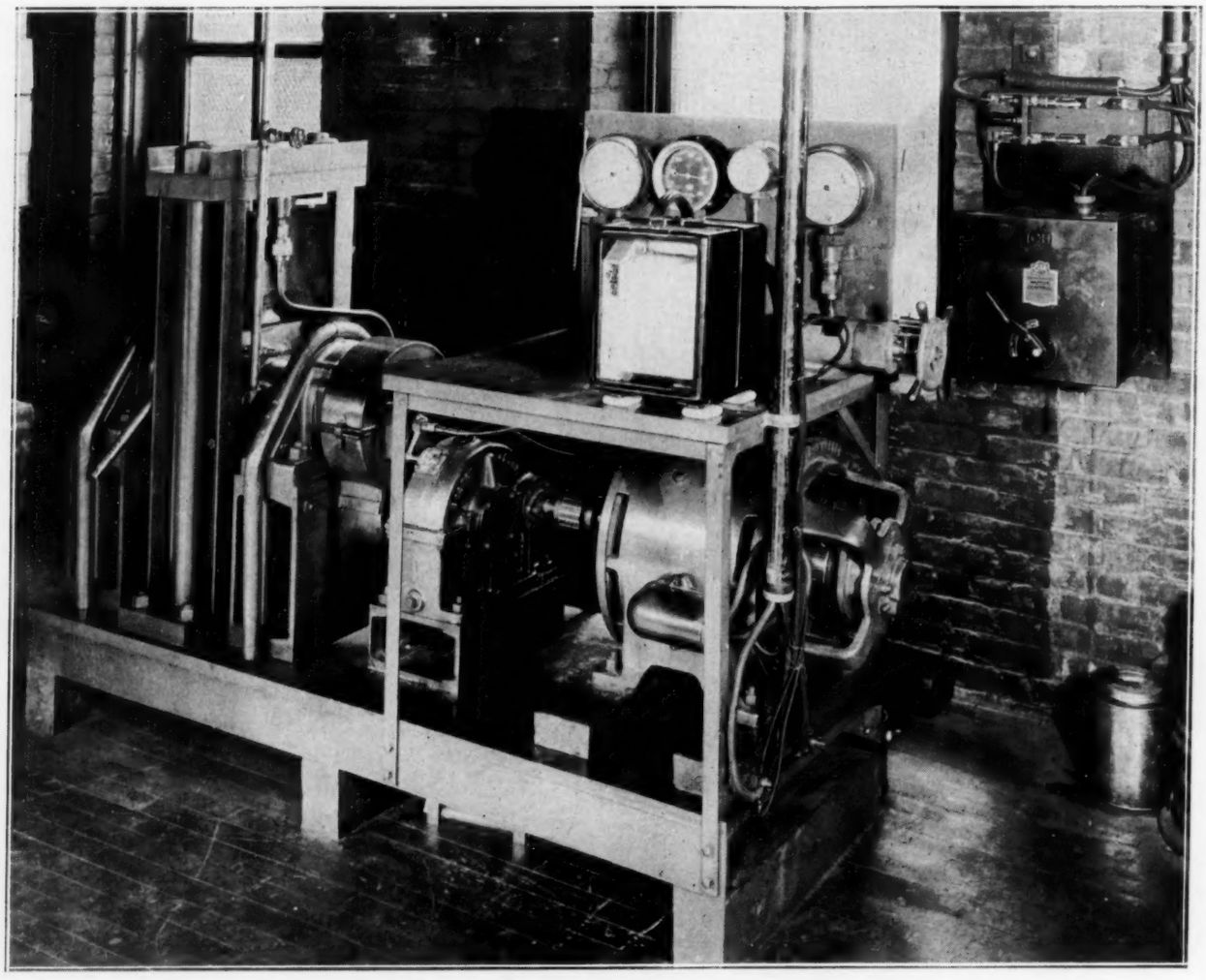


FIG. 1.

The introduction of pressure lubrication systems on the rolling mills, is one of the most important steps toward better lubrication. These systems are not 100% perfect as yet, however, they are being rapidly improved.

The pressure system gets the lubricant where you want it, when required and cuts down the possibility of a bearing going without grease because someone forgot to apply it.

The speaker believes some of the cases where systems did not appear to give satisfaction, the trouble was not in the system, but in the lubricant. Roll Necks are subject to high pressures and therefore, the lubricant must be one whose film will not be broken due to these pressures.

It is true, the grease need not be as heavy as where it was merely packed against the neck, but nevertheless, a film of lubricant must be maintained if hot necks are to be avoided.

The speaker is firmly convinced that the combination of pressure systems and Graphite Grease is one that will be of great benefit to the rolling mill industry.

SECTION 2

Testing of roll neck greases in the mill is often a very expensive proposition, especially if the lubricant should fail and cause the mill to shut down for any length of time.

It was, therefore, felt advisable to endeavor to make Laboratory tests to determine before-hand what might be expected of certain lubricants.

After investigation, no equipment could be found where rolling mill conditions could be duplicated.

A machine was therefore designed which would meet the conditions. This machine is shown in Figure 1 and consists of a shaft mounted on roller bearing pillow blocks and driven through gear reducer by 7½ HP. direct current variable speed motor.

On the center of the shaft, a removable sleeve is provided; on this sleeve the bearing is placed. The load is applied by means of a hydraulic cylinder. Maximum load being slightly over eighteen tons.

Grease can be applied by packing or arrangements for pressure feed are also available. Water

can be sprayed on the shaft for cooling as is done in actual practice.

Figure 2 shows results of tests on some lubricants which are used very extensively for industrial lubrication.

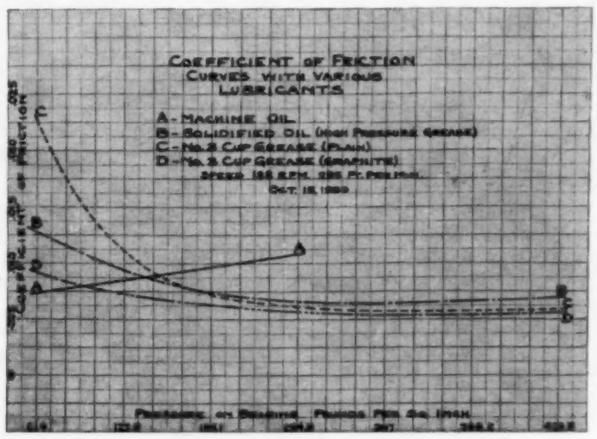

COEFFICIENT OF FRICTION
CURVES WITH VARIOUS
LUBRICANTS
A - MACHINE OIL
B - SOLIDIFIED OIL (HIGH PRESSURE GREASE)
C - No. 3 CUP GREASE (PLAIN)
D - No. 3 CUP GREASE (GRAPHITE)
PRESSURE ON BEARING

FIG. 2.

Curve A being obtained when using a good grade of machine oil. A low coefficient of friction will be noted for bearing pressures under 100 pounds per square inch of bearing surface.

Curve B shows that a solidified oil, more often referred to as High Pressure Grease, has a higher coefficient of friction than oil until a bearing pressure of 135 pounds is reached, after which same is considerably lower.

Curve C shows that a No. 3 yellow cup grease has very high coefficient of friction for loads under 130 pounds per square inch of bearing surface, but for pressures in excess of 185 pounds, has a lower coefficient of friction than either oil or solidified oil.

Curve D indicates that a No. 3 Graphite Cup Grease has a low coefficient of friction at all loads; only being higher than machine oil for loads under 90 pounds per square inch of bearing surface. The

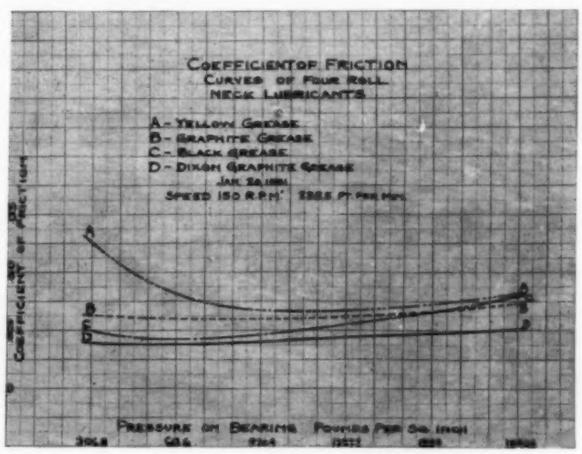


FIG. 3.

only difference between the two cup greases was the addition of finely ground flake graphite of high quality.

In making the above tests, oil was fed continously to bearing and all greases were fed through a spring grease cup so that grease was being fed as nearly as possible at same rate of feed.

Figure 3 shows results of tests on four roll neck lubricants, all of which are being used in various mills.

Curve A being obtained by testing a heavy yellow roll neck grease.

Curve B was obtained testing a graphite grease under same conditions.

Curve C was obtained by testing what had been represented as a grease containing 10% of graphite, but which was found on analysis not to contain graphite.

Curve D shows results of test on our grease. The percentage of graphite in greases B and D were the same. The quality, however, was not the same, Grease D containing a better grade of graphite also a better grade oil, though the oil was of a lighter viscosity. All tests were at a speed of 150 R.P.M.

For further comparison of the two graphite greases, refer to Figure 4. Here, Curves A and C

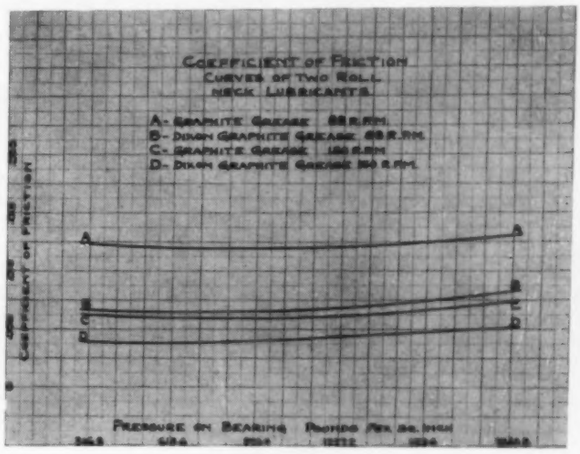


FIG. 4.

were obtained using the graphite grease and Curves B and D were obtained using our grease. Tests in this case were run at speeds of 88 R.P.M. and 150 R.P.M. You will note the grease containing higher grade graphite shows better results under all load and speed conditions.

At this point, we might just consider the subject of Graphite briefly.

Graphite is a mineral and a form of carbon. While pure Graphite is probably the softest mineral, another member of the carbon family, namely, the diamond, is the hardest. There are two distinct varieties of Graphite; the one being amorphous, the other being flake or crystalline. Both varieties can be obtained in many grades of purity.

The poorer grades are not nearly as good from a lubricating standpoint and for most conditions the flake can be considered the best for lubricating purposes. Time does not permit going into the many uses of graphite and references here will only pertain to its value as a lubricant.

Graphite has been used, as you all know, for many years, when a hot bearing would present itself. In these cases, it would be often mixed with

oil and fed to the bearing until same came back to normal operating temperature.

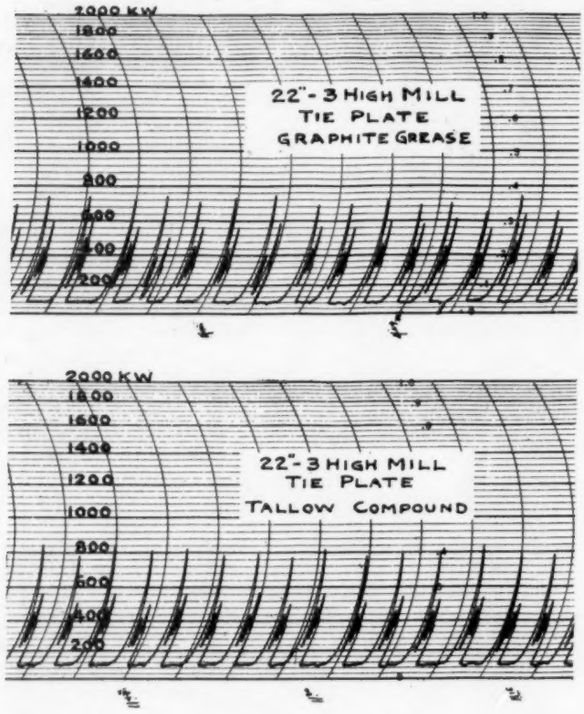


FIG. 5.

Many tests have been made with Graphite, when used in connection with oils and greases and invariably they have shown that Graphite would improve lubrication, when properly applied or when mixed with oil and greases in the proper percentage.

Illustrations of this might be that for any light duty work or where an ordinary cup grease is generally used, a Graphite Grease should not contain over 4% of a good quality finely ground flake graphite.

When referring to Graphite Greases for such conditions as exist on rolling mills, the percentage of graphite can be increased and 25% has been found to give good results.

It, of course, is not possible to use a grease of this nature for ordinary cup grease purposes, nor would the cup grease containing 4% of Graphite answer for rolling mill lubrication.

In tests conducted many years ago by Professor Goss of Purdue University, it was indicated that Graphite, when added to light oils would decrease the coefficient of friction and at the same time would permit the carrying of heavier loads.

Graphite has been used for lubrication by itself, without the use of either oil or greases, particularly in connection with high temperatures, which would cause the oils to vaporize and eventually form a residue which would prevent proper lubrication.

A specific instance of this nature is in connection with the lubrication of roller bearing wheels on tunnel kiln cars, where it has been found that the most satisfactory lubricant was a small quantity of pulverized flake graphite without the addition of any oil or grease.

A similar case to this might be mentioned, namely the lubrication of roller bearing wheels on soaking pit covers where the grease would not give satisfactory lubrication due to the high temperature encountered, which would tend to burn off all the oils in the grease and leave a heavy residue which, after a short time, would prevent the rollers from operating. The dry Graphite did provide sufficient lubrication and the temperature encountered did not have any effect on the Graphite itself.

Another instance of graphite lubrication without the aid of oil or grease, might be mentioned, that is the lubrication of the gears on a mechanical manipulator. Before using Graphite on this equipment, large quantities of cheap oil were used but after a few months operation, it would be necessary to dismantle the unit to remove the residue which, after a time, would prevent the mechanism from properly operating.

So much trouble had been experienced that when a suggestion was made to use Flake Graphite only for lubrication, the Mill Superintendent was agreeable to give it a thorough test with the result that Graphite is being used on this unit today, and has been for about two years.

The Graphite does not have to be replaced or continually added to as was the case with the oil.

There are many other uses to which graphite has been put both for lubrication and for other purposes, however, as mentioned before, time does not permit going into all of these.

SECTION 3

This, the third and last section will be devoted to results of tests conducted on various mills. These tests have shown savings in power as high as 25% with no other change in operation other than lubricant on roll necks.

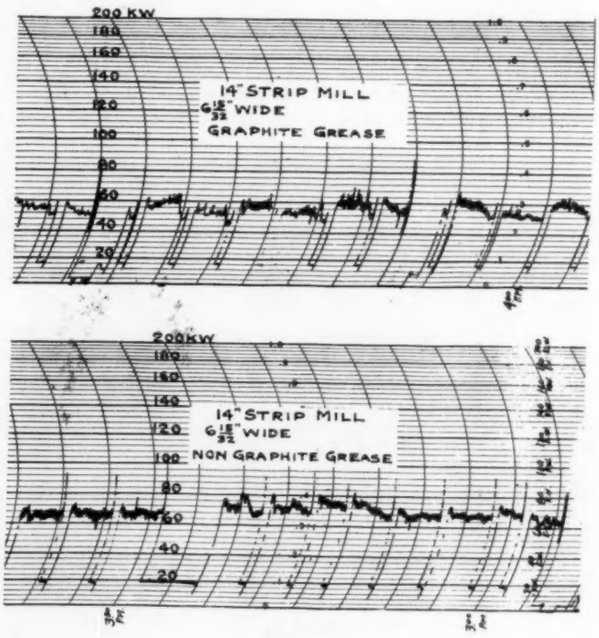


FIG. 6.

Test No. 1—This test was made on a 34" Blooming Mill rolling sheet bar stock, results being as follows:

	1st day	2nd day	3rd day
Grease used	Customers	Dixon's	Dixon's
Time rolling	11 hrs. 25 min.	12 hrs. 20 min.	11 hrs. 40 min.
No. Ingots rolled	208	233	223
Net tons rolled	676	756	724
Total KW. consumed	17100	15700	15200
KW. per net ton	25.19	22.09	20.99
Average KW. per net ton with Dixon's Grease	21.54		
Reduction in KW. per ton	3.65		
Reduction in percent	14.4%		

Test No. 2—This test conducted on a 22", 3 high bar mill rolling tie plate, results being as follows:

Average power consumed rolling with #4 Tallow Compound	255 KW.
Average power consumed with Dixon's Graphite Grease	230 KW.
Saving in Power	25 KW.
Average friction load with #4 Tallow Compound	115 KW.
Average friction load with Dixon Graphite Grease	95 KW.
Saving in Power	20 KW.

Since on this particular operation, the time rolling and the time idling were approximately equal, the average saving would therefore be 22½ KW.

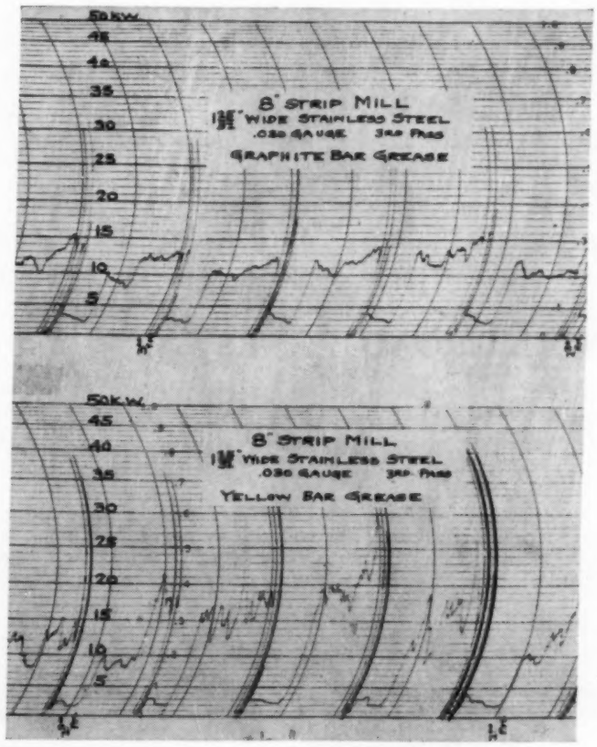


FIG. 7.

Figure 5 plainly indicates the cycle of operation.

The reduction in power consumed, especially on the last pass, can readily be noted by referring to the charts.

Test No. 3—This test was made on 12" cold strip mill rolling copper 7½" wide with a starting gauge of .028" and finish gauge after four passes of .005".

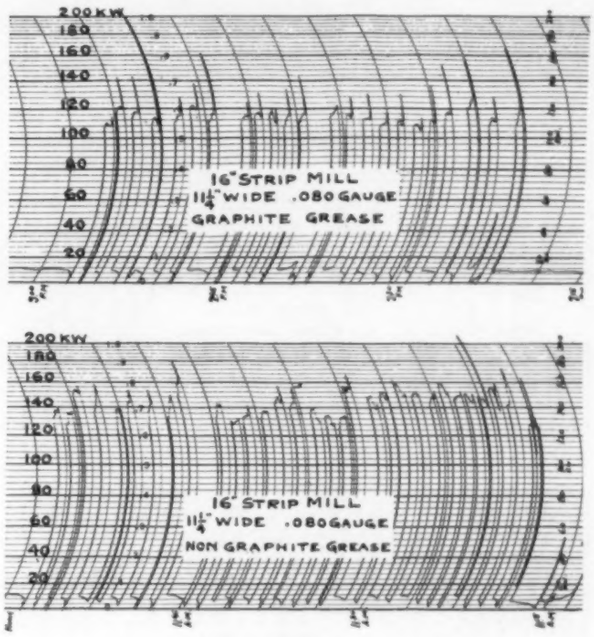


FIG. 8.

Average power consumed with non-graphite block grease:

1st pass	2nd pass	3rd pass	4th pass	Average all passes
102.8	89.8	87.5	84.8	91.22 KW.

Average power consumed with Dixon's Graphite Block Grease:

85.2	76.1	69.8	70.7	75.45 KW.

Saving in power:

17.6	13.7	17.7	14.1	15.7 KW.

Average savings—15.7 KW. which equals 17.2% of 91.22 KW.

Test No. 4—This test was made on a 14" cold strip mill rolling steel 6-15/32" wide:

Average power consumed using non graphite block grease	71.0 KW.
Average power consumed using Dixon's Graphite Block Grease	57.0 KW.
Savings in Power	14.0 KW.

14 KW. equals 19.7% of 71.0 KW.

Figure 6 shows portion of watt meter chart taken on this test.

Figure 7 shows a portion of chart taken on a test on an 8" cold strip mill when rolling 1-25/32" stainless steel .030" gauge.

Charts plainly indicate lack of uniform lubrication with the yellow bar grease. This resulted in varying neck temperatures with result that operator had to watch his screws carefully to maintain gauge. As seen on the chart, the Graphite Grease provided much more uniform lubrication with resulting lower and more uniform neck temperatures, enabling oper-

ator to maintain gauge with a minimum attention to screws.

The yellow grease cost 50% more than the graphite grease and while a high grade product was not the right grease for roll neck work, this indicates that the highest price grease is not always best suited for the job, although this is contrary to general rule.

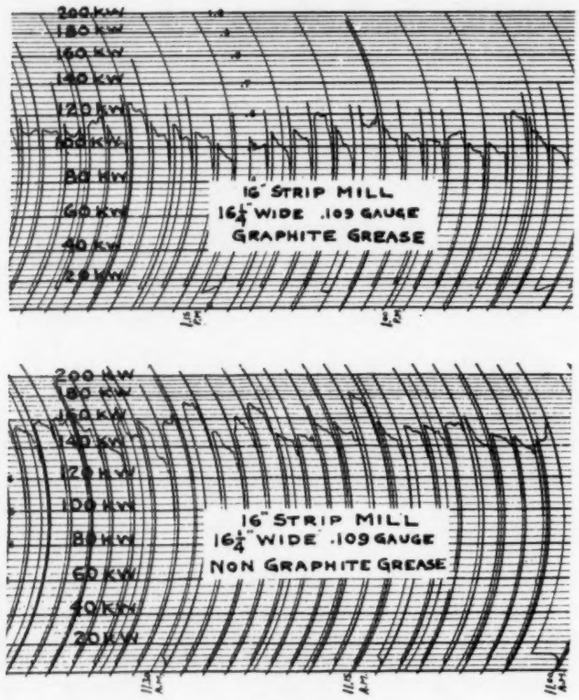


FIG. 9.

Test No. 5—This test was made on a 16" cold strip mill, rolling steel 11¼" wide, .080" gauge, with reduction of .014". The results being as follows:

Average power consumed with non graphite block grease	138.8 KW.
Average power consumed with Dixon's Graphite Block Grease	112. KW.
Saving in Power	26.8 KW.
(Equals 19.3% of 138.8 KW.)	

By referring to Figure 8, one can see the difference in power consumed when using the two greases.

Test No. 6—This test was made on a 16" cold strip mill of the same design as the mill on which Test No. 5 was made. Test, of course, was conducted in another plant and steel rolled was 16¼" wide .109" gauge. Reduction in gauge being .015".

Average power consumed using non-graphite block grease	144 KW.
Average power consumed using Dixon's Graphite Block Grease	108 KW.
Saving in Power	36 KW.
(Equals 25% of 144 KW.)	

Figure 9 shows a section of charts taken on this test and plainly indicate the 25% saving in power given above.

In closing, might state that in connection with tests, results of which are given, illustrations only show a section of charts in each case as it would be impracticable to show complete charts. The percentages however, were obtained from entire test and not from short sections shown.

Further, the speaker has in the past several years conducted a large number of tests on various types of mills and invariably found that a good graphite roll neck grease would show power savings ranging from 5 to 25% and in a few uses as high as 30%.

The savings do not stop here for with the savings in power go, not only improved mill operation, but longer bearing life, which means lower maintenance, all of which tends to reduce cost of production which is of vital interest to everyone connected with the rolling mill.

MARKED REDUCTIONS IN RAILROAD FARES

TO

CLEVELAND FOR JUNE CONVENTION AND EXPOSITION

We would ask that as many as possible, traveling via railroads to our June Exposition and Convention, take advantage of the reduced railroad fares accorded our Association by the Central Passenger Association, and through them, to most every railroad in the United States and Canada. Each and every ticket agent on the lines granting this reduced fare have the official tariff sheets on file giving explicit information and they will be very glad to enlighten any of our members making inquiry.

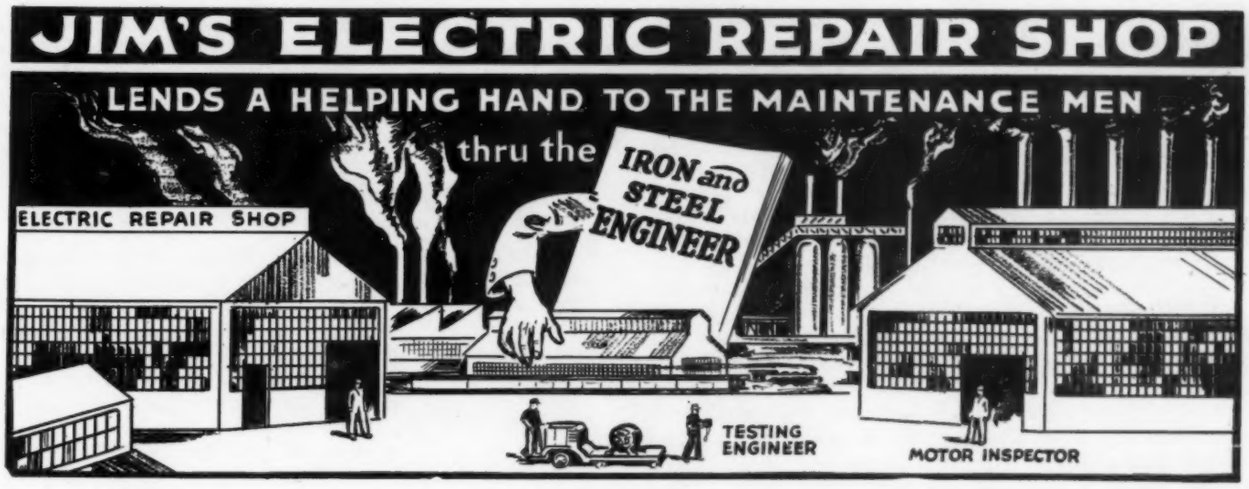
These tickets will be on sale from June 11th to June 17th, inclusive, good for return from June 15th to June 25th, inclusive, at 1½ fare for round trip BUT IT IS ABSOLUTELY NECESSARY FOR EVERY USER TO SECURE FROM OUR ASSOCIATION AN IDENTIFICATION CERTIFICATE IN ADVANCE—this is presented to the local railroad agent after your endorsement and becomes his authority for granting our members and Exhibitors this special rate. This offer is also open and available to all members of your family providing you secure from us the proper certificates in advance.

We have secured a supply of these certificates, subject to your call, and we would suggest that you immediately advise us how many you intend to use and we will send them to you at once.

ASSOCIATION OF IRON & STEEL ELECTRICAL ENGINEERS,

JOHN F. KELLY, Managing Director,

1010 Empire Building, Pittsburgh, Pa.



COMMUTATORS AND THE THREE EVILS "OIL, DIRT AND MOISTURE"

Oil is one of the greatest causes of commutator failure. It saturates the Mica parts forming the base on which dirt arrays itself, sparkling out with jewels of moisture from the cooling commutator, when the motor is out of service. Hidden from the eye it provides a wonderful path over which creepage currents glide on their way to ground when power is re-applied. You know the rest of the story.

The real solution of this problem is the elimination of oil from the interior of the motor. If this is accomplished it is comparatively easy to keep dry dirt off the commutator. In the very near future we will deal with the elimination of oil in the motor and until then we advise you to instruct your oilers

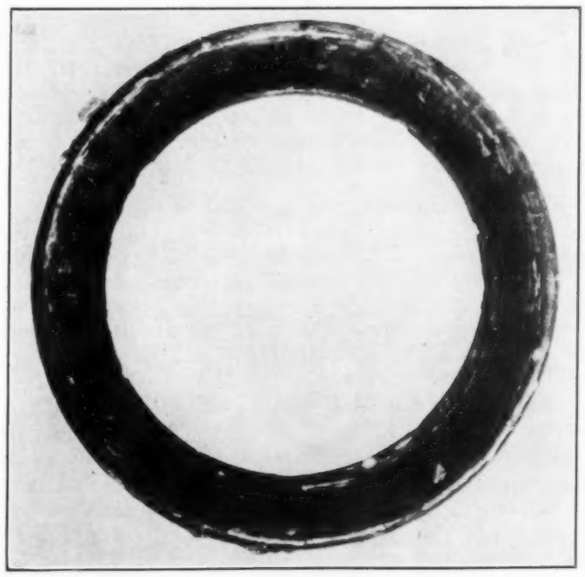


FIG. 1.

to spare the oil and save the commutators. The scope of this article is to deal with the sealing of the commutator against the penetration of oil and moisture.

In building a commutator it is necessary to insulate the bars from each other as well as each bar from ground. Mica was chosen for the insulating material primarily for its good insulating qualities and very high resistance to heat.

It is the Mica parts which become saturated with oil either in spots or as a whole. The oil carbonizes, due to the relatively high operating temperature of the commutator. These carbonized places permit creepage current to flow between the bars or to ground. As the current continues to flow, and burn the Mica the resistance of this path becomes less and less, until a dead short or ground exists.

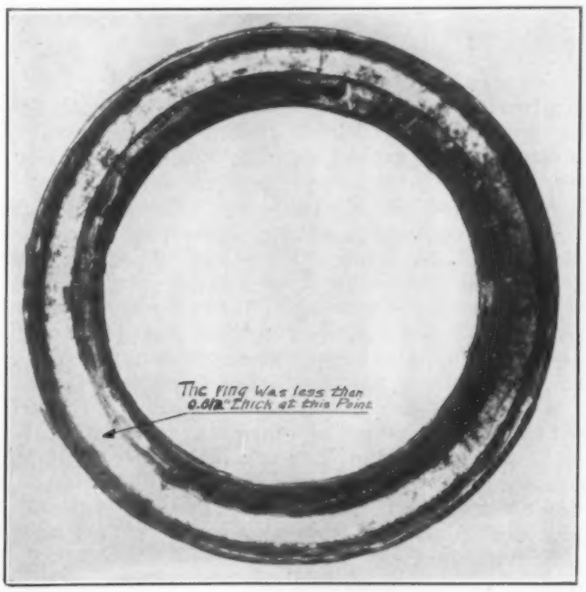


FIG. 2.

Some grades of Mica will absorb a large amount of oil while other grades will absorb very little. In order to understand this better it will be interesting to briefly describe the process of making Mica Plate.

Mica Plate is made of Mica splitting held together with a powdered bond which is applied by the Tower process. This process distributes alternate quantities of Mica splitting and bond, on a table below after which the bond is liquidfied by pressing in a hot press.

It is essential that the entire surface of each splitting be entirely covered with the bond. In the pioneer days commutator Mica Plate was manufactured with a liquid bond whose quantity could not be accurately controlled resulting in excess bond which would squeeze out when the commutator went into service. This necessitated retightening commutators in service until this excess bond was pressed out. To eliminate this trouble some manufacturers of Mica Plate have swung to the method of using insufficient amount of bond even dropping as low as 2%. In the long run this is worse than excess bond, because the entire surface of the splittings are not covered with bond. The spots not covered will provide ideal pockets in which oil and moisture may collect. Furthermore, Mica Plate having insufficient amount of bond is dead and does not have sufficient expansion and contraction qualities required to make a good commutator.

The Mica V Ring is the most vital part of the commutator, in that it must insulate a mass of copper from the commutator core and withstand the mechanical strain of the vise which holds this mass in place. The dimensions, such as angles, diameters and thickness must be held rigidly to specification limits. Failure to adhere to these vital points can be better illustrated by a set of photographs of two front Mica V Rings which were assembled in the same commutator under equal pressure and temperatures. These Mica V Rings when removed from the commutator, were photographer by placing a 1000-watt lamp behind them so that the only light which could be visible to the camera, must pass through the Mica V Ring. The Mica V Ring in Fig. 1 shows no light spots while Fig. 2 shows a light ring on the 3° angle, which was due to the shifting of the Mica and crushing of the bond under the pressure, because the ring did not have the correct dimensions and construction. One place the shifting was so great that the remaining Mica was only .012" thick.

This discussion is interesting because it portrays to the Maintenance Men what is required to produce good commutator Mica Plate and V Rings. The quantity of this material which he purchases does not warrant his preparing specifications to purchase this material, nor can he afford to provide an elaborate inspection department to see that such specifications are adhered to, should he desire to do so.

When re-Micaing a commutator the Mica strips used between the bars should have a coat of surface shellac to cement the bars and Mica strips together to prevent oil and moisture from creeping along the side of the copper bars and Mica strips. If the Mica Plate does not have this applied as a part of the manufacturing operation, a thin coat should then be applied before assembling.

To seal the commutator against oil and moisture, all cracks and pores in the mechanical structure must be welded or replaced as any oil which enters the mechanical structure of the commutator will be thrown by centrifugal force through the Mica parts. The clearance between the front steel V Ring and the commutator spider must not have more than a sliding fit. The front end of the tightened commutator core should be given a coat of thin shellac and then a heavy coat of black plastic varnish to seal the necessary opening so that oil cannot enter the interior of the commutators by these joints.

In the article in March we recommended that the angles of the steel V Rings and the assembled segments be given a thin coat of shellac before assembling. This is done so the oil cannot creep along the steel V Ring under the Mica V Ring, and be thrown into the Mica V Ring by centrifugal force. And for the same reason by painting the copper V's the oil is not so likely to creep along the top of the Mica V Ring into the assembled segments.

Many operators object to this procedure by maintaining that it is impossible to dis-assemble the commutator without destroying the Mica V Ring. This is true but 95% of the time the reason for removing the Mica V Ring is because of a short circuit between bars or a ground, in either case the ring having been destroyed to such an extent, that it should not be used. On the other hand the number of failures due to oil will be reduced to such an extent that it pays many times over for the rings which could not be saved.

Insulation On Commutator V Ring.

Treating the front Mica V Ring is a very important operation. It is best treated in the following manner:

1—Clean the Mica V Ring thoroughly with sand paper, making sure that the front end of the bars and the end of the steel V Ring are also cleaned.

2—Paint the cleaned surface with a thick coat of heavy shellac.

3—Wrap the Mica V Ring with one layer of untreated soft twine. The insulating compound does not adhere to a hard treated twine.

4—Saturate this twine with a coat of shellac and iron thoroughly with a hot soldering iron.

5—Iron in, two more coats of shellac.

6—Apply a coat of red oxide cement over the Mica V Ring, covering the front end of the bar. Let this coat dry without brushing as this cement generally has a very glossy surface and dries rapidly. If it is brushed while drying the brushing operation spoils the gloss.

The motor inspector should endeavor to wipe the Mica V Ring free from dirt on all D.C. machines once every day. If there is an excess of dirt and oil, the Mica V Ring should be cleaned every eight hours. To the average operator this seems like unnecessary work, but if followed the results obtained will be well worth the trouble.

HOW TO RE-MICA A COMMUTATOR*

The question of how to order Mica strips for repairing commutators has been asked by many maintenance men. The manufacturer of the original motor will supply the Mica strips in one of two ways, namely: (1) Punched to an unfinished size, and (2) rectangular Mica strips.

When the V's and necks of the copper bars are punched to an unfinished size for manufacturing purposes, the Mica strips will be punched in the same manner. This Mica die will leave 1/16" of material on each side of the V for finishing purposes. This is shown in Fig. 3.

*Answer to J. H. L. Question February Number.

When the Mica strips are received in this form they can be finished very easily by pasting to the copper bar with shellac. When the shellac is dry, place the two in a vise with the Mica strip toward

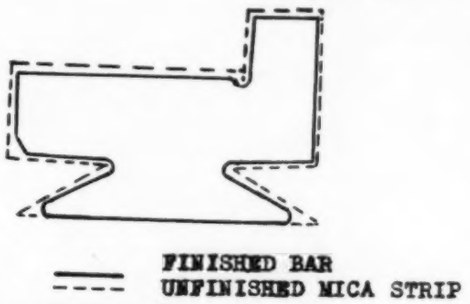


FIG. 3.

you and cut the V's to the same size as the copper V's. Be sure that the stroke of the knife is toward the copper. In this manner the Mica will cut without tearing. It may be necessary to take a finishing cut with the knife file. The file must be handled in the same manner as the knife.

When there are only a few commutators of a given size to be manufactured, it does not pay to make a die for punching the V's and neck in the rough, for it is cheaper to make the commutator from the rectangular copper bars and Mica strips. Where this condition exists, the Mica strips will be rectangular for repair purposes.

When rectangular Mica strips are received it is best to paste them to the bar with which they will be used. Cut the V in the same manner as mentioned in the foregoing discussion. See Fig. 4.

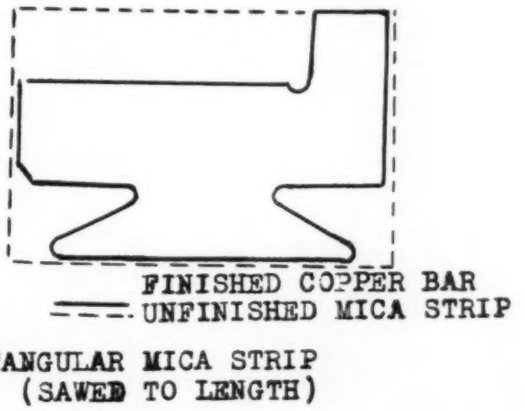


FIG. 4.

When a complete commutator is to be refilled a set of Mica strips will be required. Some repairmen do not care to use the Mica in either of the above mentioned forms because it requires too large a stock to take care of a varied line of motors as is usually found in the average steel mill. Under these conditions it will only be necessary to carry the Mica Plate in sheet form for three standard thicknesses.

By careful consideration the amount of scrap can be kept to a minimum by the following method:

Assume that the copper bars (finished) are 5/8" x 3". if the sheet is 24" x 36", it can be cut into six strips 6" wide and 24" long.

Apply a coat of pure heavy orange shellac sparingly on the one side of each strip. Lay the copper bars on the shellaced side in the manner shown in

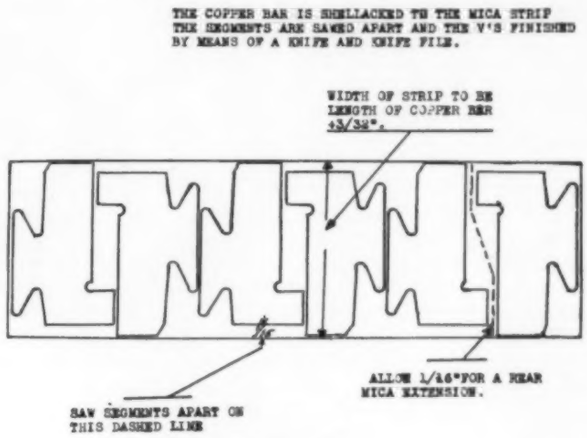

THE COPPER BAR IS SHELLACKED TO THE MICA STRIP
THE SEGMENTS ARE SAWED APART AND THE V'S FINISHED
BY MEANS OF A KNIFE AND KNIFE FILE.
WIDTH OF STRIP TO BE
LENGTH OF COPPER BAR
+3/32".
ALLOW 1/16"FOR A REAR
MICA EXTENSION.
SAW SEGMENTS APART ON
THIS DASHED LINE

FIG. 5.

Fig. 5. It will be possible to get eight copper bars on each strip.

A rear Mica extension is desirable and can be obtained by laying the copper bar on the plate so that there will be 1/16" of Mica extending from the rear of the bar. Any Mica which may extend in the front of the bar can be removed by the machine tool after the commutator has been assembled or with a knife when the V's are finished.

After the shellac dries, saw the segments apart (as shown in Fig. 5 by the dashed line) with a band saw if one is available. If a band saw is not available they can be cut apart with a coping saw. When using a coping saw use a piece of fuller board placing the same in the vise so that the edge is even with the place where the Mica Plate is to be sawed. Care should be taken so that the stroke of the saw will be toward the piece of fuller board in order to prevent flaking of the Mica. If a band saw is used, the set should be small and the throat in the table for the saw to pass through should be very narrow.

After the strips have been cut apart, the V's can be sawed out with the band saw or cut out with a knife. It may be necessary to take a finishing cut with a knife file before assembling.

After the V's have been finished, do not remove the Mica strips from the copper bars but assemble them while they are stuck together. When the commutator bars are to be assembled shellac the other side of the strip. This will cement the assembled segments into one solid mass when the commutator is tightened.

Before tightening the commutator first align the bars so that they will be parallel with the carbon brush and see that they are aligned with respect with the manufacturer's requirement concerning the centerline of the armature slot. Heat the commutator to a temperature of 125° to 150° C. and tighten while under pressure as discussed in the March issue.

The Electric Furnace as a Metallurgical Tool in the Steel Industry†

By CHARLES McKNIGHT*

The aim of this paper is to discuss the electric furnace of the steel industry from a purely metallurgical standpoint. It does not concern itself with electrical, mechanical or refractory details better left to the adequate attention of the experts in these respective fields.

The steel furnace has progressed from the rude forge through the solid fired melting furnace, such as the crucible furnace of the tool-steel maker or the air-furnace of the iron foundryman, to the gas or liquid-fired regenerative open hearths of the modern steel plant. The final and revolutionary step to the electric furnace did entirely away with any fuel, thus eliminating the inefficiencies, contaminations and waste-products of combustion and increasing our useful commercial range of temperatures by a third or more. At the same time it put in the hands of the steel-maker a most flexible tool. Unfortunately, it was hailed as a panacea for all the ills of the melting-shop. It is not that and a proper realization of the limitations, as well as the advantages, of the electric furnace is essential to the metallist who would make the most of this valuable aid.

Modern electric furnaces in use in the steel industry are divided into the following types:

Direct Arc—Indirect Arc—Induction—Resistance.

The resistance type of melting furnace for steel can be dismissed in a few words, as its only use is in small crucible furnaces for use in the laboratory and even there it is giving way to other types. Similarly, there are very few indirect arc furnaces installed in steel mills or foundries, although they are very popular in the non-ferrous industries. Some cast irons, either alloy or of special nature, are made in this type furnace.

The high-frequency induction furnace is the latest development, although in another form it was one of our oldest furnaces. The old form jogged sedately along on current at 60 cycles per second and was very difficult to operate, so, in keeping with the age, Professor Northrup of Princeton University speeded up the induction furnace and fed it current with a frequency on the order of a radio wave. At first it was a laboratory tool and was quite complicated with its huge bank of condensers—many times more bulky than the furnace itself—and its mercury arc and its nitrogen tank and, too, it had nasty little tricks in its infancy, such as poisoning its keeper with mercury fumes. All that has been done away with; the oscillating current of somewhat lower frequency is now generated by machinery and there is no longer any mercury arc. Simultaneously, the induction furnace, like the country at the fall elections, has gone democratic (but not wet) and has moved from the laboratory out to the mill, where it is used for making the highest grade steels and alloys, such as tool steels, corrosion-resisting steels, iron-nickel alloys of the high magnetic permeability and similar alloys having low co-efficients of thermal expansion.

What are its advantages? Purity is the most important as there is practically no chance for contamination. Accuracy is another. Ordinarily when specifying the chemical analysis of steel, a range or spread must be allowed, due to the impossibility of hitting the desired analysis exactly. With the induction furnace this spread is reduced almost to the point of elimination. Homogeneity of product is a third advantage. The motion in an induction furnace is constant and forceful, the center of the bath sometimes rising several inches higher than the periphery. This stirring results in great homogeneity of the bath and is particularly valuable when making steels containing heavy, sluggish alloys such as tungsten. Finally, the induction furnace has a great advantage in its applicability and the wide range of products that can be made in it. It is of value in making the nickel iron magnetic alloys which are highly oxidized and, opposite application, is used for remelting "stainless steel" scrap because the oxidation losses in it can be reduced to a minimum.

We have left for consideration the direct arc furnace, the keystone of the electric furnace industry —at least for the present. Commercially brought into existence by Heroult at the turn of the century, it has in thirty years firmly established itself and accounts annually for about a half million tons of first-grade steel products. The advantages, besides the ones already mentioned over combustion furnaces, are extreme flexibility and ease of control metallurgically speaking, the greater range of temperature it offers, the fact that refinement by oxidation and/or reduction can be effectively carried out and a product that is conceded to be the best obtainable today in quantity and at an attractive price.

All electric furnace practice is sub-divided into acid process and basic process, but the only furnace in which the process differ radically is in the arc type. The acid process can be readily dealt with in a paper such as this because it is (on paper) simple. A cold metal charge is melted down on a sintered sand hearth; the protective slag comes from the iron oxide of the charge and the sand from the hearth. The carbon in the bath is reduced by oxidation to the desired point and the heat is then brought up to proper tapping temperature, while simultaneously deoxidation and quieting of the bath is effected by the silicon from the slag and hearth. As soon as this is accomplished and de-oxidizers, if any, added the heat is ready to go. Good practice, the author believes, dictates the addition of some lime to the slag, when it will, if in prime condition, have an olive green color with a glassy surface and a porcelainic fracture when cold. Paradoxically, in any process when a melter desires to make good steel, he puts all his effort on his slag. If that shapes up nicely, the metal will make itself and a steel-maker is therefore really a slag-maker.

The acid process is very popular in the steel foundry and a large proportion of the steel castings

*In Charge, Alloy Steel Development, The International Nickel Company, New York, N. Y.

†Presented before A. I. & S. E. E. Heating and Welding Conference, January 21, 1931, Pittsburgh, Pa.

made are of acid electric furnace steel. As there is no reduction of phosphorus or sulphur by this process, it is necessary to start with a high-grade charge. Otherwise the process is well adapted to foundry practice. It is a case of melt down, knock down the carbon, run out the heat. For small or intricate castings, or castings from high-alloy metal that is inclined to be sluggish, the high temperature is a decided advantage and the viscous character of the acid slag decreases the likelihood of slag being entrained in the steel with subsequent deleterious effects on the casting.

The basic steel-making process in the arc furnace is much more complex. Its re-actions, apparently simple, are the moot point of much discussion and there are a number of inexplicable phenomena, or accidents, which require explaining.

However, according to the rules, the following is the accepted procedure. The process divides itself in two periods; the oxidizing and the reducing. The oxidizing might also be known as the "melting phase" and the reducing period as the quieting phase and both are refining in nature. The phosphorus and sulphur—by tradition the two worst impurities in steel—are more or less completely removed; the phosphorus by the oxidizing slag and the sulphur by the reducing slag. (Mnemonics are helpful sometimes if one has trouble remembering which is which. O and P, R and S are side by side in the alphabet. However, it is of no great importance because, even if the melter forgets, the oxidizing slag will still remove phosphorus and won't touch the sulphur).

During the oxidizing period the charge is melted, the oxidizing slag shaped up, the carbon and other oxidizable elements reduced to the desired point and, finally, the slag is removed to make way for the new reducing slag. The oxidizing slag consists essentially of lime and iron oxide. The lime is always supplied, sometimes as limestone, but the iron oxide can either come from the scale and rust on the scrap or, if the charge is too clean, it can be added in the form of mill scale or iron ore. Usually at least part of the lime is charged on the bottom before the furnace is charged. This slag forms as the charge melts down and does not often require any attention from the melter. Occasionally ore or mill scale must be added to keep up a brisk oxidizing action. As the heat progresses the melter informs himself, either by fracture tests or quick laboratory determinations or both, as to the chemistry of the bath, particularly as regards the carbon content. The metal is in suitable shape when it has the desired carbon, the phosphorus is sufficiently low and the bath is at a high enough temperature. When these conditions obtain, the oxidizing slag is scraped off the surface of the molten charge, usually by means of a wooden rabble. The metal must be scraped clean because phosphorus will be reduced into the bath from any remnants of slag when the second slag is on. This slagging off marks the end of the oxidation period.

It should be noted that for phosphorus removal the slag should be very basic and the temperature should be low. It should also be noted that the control of oxidation is in the hands of the furnace man and that he may desire to completely oxidize, partially oxidize or melt with practically no oxidation. The first method involves the use of a slag high in iron oxide and is advantageous in that dirty scrap and scrap high in phosphorus can be used, but oxidizable elements such as manganese, chromium and vanadium are lost. Melting with only partial oxidation requires good scrap and a careful temperature control. It is probably the most favored of the three methods and usually indicates that the melter is catching the carbon coming down. The oxidizable elements are, for the most part, not lost, the metal is not apt to be over-oxidized, resulting in easier final shaping up of the heat. The last method is more a theoretical one as melting without oxidation means the carrying of a second, or reducing, slag from the beginning of the heat. It is used infrequently except in cases where it is desired to reduce the alloy loss to a minimum.

When the metal is bare after slagging-off offers an unusual opportunity for direct action. If the steel must be re-carburized, some carbon can be added at this point either as ground carbonaceous matter or washed metal or pig iron, although it is moot whether or not this procedure is desirable. Personally, the author confesses to a sneaking likeness for adding some of the ferro-manganese and a little good deoxidizer at this time—not much, just a "soupcon," as the chef say, maybe a nugget or two of calcium silicide or some other alloy with a bite to it. It is unorthodox but helpful and the oxidation products are all translated to the slag before the heat is finished.

The deoxidizing period starts with throwing on the bare metal a slag mixture of lime, flourspar and ground coke, ground electrode or other carbonaceous material. The ratios depend on the degree of reducing power demanded and, parenthetically, the carbon in the mixture is on rare occasions supplanted by some other reducing material such as ground ferro-silicon or aluminum. This second slag is characterized as being either a "white" slag or a "carbide" slag, depending on its reducing power and it is this slag which renders the basic electric furnace process fundamentally different from any other steel-making process.

The slag-material blanket acquires heat from the furnace, the metal and the arc. Some of the carbon is burnt; some goes to deoxidize the steel; eventually there is little left in the slag but the furnace conditions are at equilibrium—neutral. At this point the slag is white and foamy. If the consistency is right—and the flourspar determines this—the slag will foam and roll and look for all the world like the foam on beer—if you know what I mean. With further additions of carbon the slag takes on a gray color. This results from the combination in the heat of the arcs of carbon and lime to form calcium carbide (CaC_2). When this slag cools it disintegrates and falls in a short time into a grayish powder, which, on being moistened with water gives the characteristic odor of acetylene, the re-action product of water and calcium carbide. When these conditions obtain the slag is known as a "gray" or "carbide" slag.

The reducing slag, shaped up and worked on by the melter, gradually takes up from the metals the oxides it carries and reduces the sulphur, which goes into the slag as calcium sulphide. As soon as the slag is formed and is white, the remainder of the ferro-manganese may be added and, as the heat

progresses to deoxidation, ferro-chromium, if used, is added. Nickel and molybdenum may be added at any time. When it is judged that the reducing slag has accomplished its purpose, the ferro-silicon is added to the bath, the temperature is adjusted, any final additions of alloys, such as ferro-vanadium, or deoxidizers, such as aluminum, are made, and the heat is finished and tapped.

Even an inadequate discussion of slags is long, but it would not do to dismiss the subject even now without a caution. We speak so glibly of reducing slags and deoxidation that perhaps we simplify too much and take for granted that which we hope for. Deoxidation and degasification have become confused. The carbide slag does not degasify. It quite frequently happens that a heat of steel containing considerable quantities of silicon, nickel, chromium or other alloys, made under apparently the best conditions with little oxidation at first and subsequently with a good reducing slag, will show evidence of containing large quantities of gas after being tapped, rising in the mold or "cauliflowering." Improving the practice by utilizing slags higher in carbide and/or by adding more and more powerful deoxidizers do not help.

From the very beginning of the use of electric furnaces for steel manufacture we have heard of its deoxidizing powers, its ability to maintain reducing condition from first to last, if desired, and have learned to think that the more reducing the condition the better the product. Also, deoxidation has been so emphasized that it has completely overshadowed degasification or, what is more likely, the two are confused. It is asserted by some authorities that, while steel in the open hearth process picks up from the flame sweeping over the bath such gases as hydrogen, nitrogen and carbon monoxide, the bath in the electric furnace is so protected that it becomes very improbable that these gases will be dissolved by the metal. It is conceivable and sometimes occurs that the bath will be completely deoxidized and yet carry in solution a volume of gases several times that of the steel itself, these gases being principally nitrogen and hydrogen, the former inert, the latter reducing in character and thus conforming in chemical character to the prevailing conditions at the end of an electric furnace heat.

We speak vaguely of degasification and of performing this operation by the addition of silicon, manganese, aluminum, etc. to the bath. Yet the mechanism of degasification is shrouded in mystery and no satisfactory explanation is forthcoming.

Confronted by this condition of wild metal and rising in the mold of heats apparently thoroughly deoxidized it is recommended that the practice be reversed. If the metal is heavily oxidized to start with, quieted judiciously between slags and finished under a good white or light carbide slag (not too gray) little trouble will be experienced. This thought is particularly commended to melters who have to deal with corrosion-resisting steels and irons high in nickel and chromium ("17:18", for example), similar alloys for heat-resistance work and the nickel-irons having special magnetic or thermal expansion characteristics ("permalloy" and "Invar," for example).†

†A fuller discussion of this may be found in the Transactions, American Society Steel Treating, p. 771 et sq., Vol. 8, 1925.

The advisability of using a final deoxidizer, such as aluminum, is subject to much argument. It is held, and wisely, that it is best to make the steel in the furnace without recourse to doping. One of the best reasons for this tenet is that, by doing away with all final additions, it avoids excesses which are unquestionably bad for the steel. We admit, however, to a heretical feeling that a judicious quantity of aluminum added on a rod under the slag at least five minutes before tapping, although unnecessary perhaps, frequently improves the heat and tends to eliminate the last removable vestiges of oxides and gases.

The list of final deoxidizers includes aluminum, magnesium and its alloys, zirconium, calcium silicide and many others, even uranium. It is not in the province of this paper to point out any one as the best or to say that any is necessary, but it is permissible to say that for certain purposes certain deoxidizers are useful. Calcium silicide is an excellent deoxidizer both in the furnace and as a ladle addition when the melter deems such practice good. It is particularly helpful in the manufacture of the "stainless steels" (high chrome-nickel) and markedly improves the characteristics of the metal. The same is true of high-nickel irons. Magnesium can be used in the higher nickel-chromium-iron alloys, such as for heat-resistance. Only don't attempt to add metallic magnesium to a high-iron heat. The action is usually explosive. Magnesium is obtainable in alloy form (such as 50 Mg 50 Ni) and as such can be safely added.

A word about refractories. These are the limiting factor of the further development of the electric furnace and its uses. Silica (sand or brick) and magnesite have been the stand-bys for years. Recently the refractory manufacturers have introduced clay refractories having alumina incorporated in them. Carborundum and similar electric-furnace-born materials have had some use but are handicapped by a high rate of thermal transmission and a high cost. In the high frequency induction furnace costly clay and graphite crucibles used to have a very limited life. Now magnesia—and, to a lesser extent, zirconia—is giving very satisfactory results.

Thus far, we have occupied ourselves in describing the electric furnace as a tool. Let us see what this tool can and is being used for.

1. Steel Mill and Forge:

Probably first in tonnage is the steel mill and forge shop, where the electric furnace is utilized because of the superior quality of the steel made. Steels for aeroplane and automotive work are often specified electric furnace.

2. Foundries:

Next, comes the steel foundry, which the electric furnace has practically revolutionized, because of its usefulness and flexibility. Today most small steel castings, up to say fifty pounds in weight, are made in the electric furnace. Cast irons, particularly those containing alloys, are often made in these furnaces and the growth in the use of these special irons has been tremendous in the last few years.

3. Duplexing:

In some of the large steel melting shops, alloy and special quality steels are made in the electric furnace by duplexing, or taking molten steel from

large open-hearth furnaces and further refining it in smaller arc furnaces.

4. Tool Steel:

Tool steel was for over a century essentially the product of the crucible. In fact, crucible steel and tool steel were synonymous. Today the great bulk of tool steels are made in the electric furnace and there are few who claim that crucible steels are superior. This is one of the fields in which the high frequency induction furnace is being introduced.

5. "Stainless Irons":

What a blessing a generic and descriptive name for these alloys would be! It is essential that the carbon be low in these alloys and that oxidation of alloys (chromium) be reduced to a minimum. With the arc furnace, the first can be accomplished under the oxidizing slag before the chromium is added. Under the second reducing slag the ferro-chromium can be added with minimum oxidation loss. By the same token, it is only in electric furnaces that "stainless" scrap can be melted, but for this the induction furnace is better than the arc, as it can melt this scrap with no loss of chromium and no carbon pick-up.

6. Other Highly Alloyed Steels:

More and more we encounter complex steels or, rather, iron alloys. We used to speak of ternary and quaternary steels but now we have almost reached the sesqui-centenary steels; These steels, high in nickel, chromium, molybdenum, tungsten, vanadium, etc., in groups or all together, can best be melted with electricity—usually in an induction furnace.

7. High Nickel Alloys:

The peculiar effects of nickel in increasing amounts on the nickel-iron system are influenced largely by the purity of the alloy. Therefore, magnetic and thermal alloys are always made in an electric furnace. It is interesting to note that, contrary to general opinion, it is possible to get an almost carbon-free product (carbon not more than .02%) in an arc furnace by proper choice and use of electrodes and slag.

8. Tungsten Carbide:

This metallurgical novelty, perhaps industrially revolutionary, has been made by pressing into molds and then sintering at high temperature. It is possible, according to the author of a paper presented at the last meeting of the Iron and Steel Institute, to melt this material and cast it into the desired shape at a temperature of 3500-4000 deg. F. by using an induction furnace of extra-high frequency (about 20,000 cycles per second).

The development of the electric furnace was seriously handicapped at the start by a dearth of capable operators—or rather by an abundance of tyros who considered themselves experts. This condition no longer obtains and the future of the electric furnace lies clear ahead. The metallist to whom has been entrusted an electric furnace of any type should realize the elasticity, the possibilities of this tool and should match them with his vision. Electric furnace practice, even thus early, is set and hide-bound —"Joe Gish says he does so and so" or "It's in Mr. Ducrot's book." The operator who interests himself and experiments with new refractories and electrical conditions, who varies his procedure, and uses more and different slags for different purposes, who ascertains how to put into his molten metal a quality or characteristic that makes it more useful when a finished product will not only be amply regarded but will have contributed to the advance in the development of engineering materials.

The Manufacture of Welding Wire†

By GEORGE S. ROSE*

Inasmuch as those present are primarily interested in electric welding, this paper will deal with the manufacture of bare steel electrodes.

With the large portion of the electric welding being done with wire made to American Welding Society Specification E-#1-B, we shall discuss the melting, rolling and drawing of steel with a carbon content of .13 to .18%, although a considerable quantity of lower carbon steel is used.

Steel for electric welding wire is melted in the basic open hearth furnace and should be of a type called effervescing or rimmed steel. In the manufacture of steel for electric welding wire, particular attention must be given to the selection of raw materials. Phosphorus and sulphur are well taken care of through the use of selected scrap steel and the general run of cold pig iron and hot metal, but the residual silicon content of the iron must be carefully watched in making effervescing steel. The average analysis of desirable iron is:

Silicon	1.05	1.20%
Sulphur	.028	.037
Phosphorus	.240	.270
Manganese	1.60	1.85

The hot metal constitutes about 55% of the total charge of the open hearth furnace, scrap about 30%, limestone 8 to 10%, with ore and cold pig iron presenting variable figures depending of the analysis of the charge when fully molten.

The slag must be heavily basic and to keep it so, lime additions in the furnace are frequent. Lime and limestone amount at times to as much as 300 lbs. per ton of steel produced for welding wire.

In some steels of the effervescing type, aluminum is added in the ladle or molds in order to keep the steel quiet, this applying more to heats which show a disposition to be wild. In the case of steel for welding wire, care must bet taken to add no aluminum so that some heats which may be intended for welding wire and which turn out to be hard to control without the use of a deoxidizer are later diverted to other uses by manufacturers who have such outlets.

†Presented before A. I. & S. E. E. Heating and Welding Conference, January 21, 1931, Pittsburgh, Pa.

*American Steel & Wire Company, New York.

Corrugated molds are desirable and should at all times be used to eliminate ingotism. Care must be taken to have the molds clean and smooth before teeming, as defects in surface caused by dirty or rough molds, or by splashing due to incorrect teeming methods, will remain in the steel through the finishing processes.

The ingots, when delivered to the blooming mill, are allowed to soak in the pits for at least two hours at a temperature of 2000 to 2200°F. The particular mill in which we manufacture this steel gives the blooms 18 passes in a 40 inch stand and 7 passes in a 25 inch stand, reducing to 4"x4"x42" billets from 22"x25"x72" ingots.

All welding wire heats are of re-checked analysis and cropping is carried out accordingly. Ladle analyses are run on tests taken from the 4th, 12th and last full ingot of each heat and the method of dissecting these ingots for analysis re-checks is determined from the results of the ladle analyses. All steel for welding wire is cropped at least 30% at the top and 10% at the bottom, this material being discarded.

The 4th, 12th and last full ingot are dissected so as to obtain billet re-checks from various portions of these ingots.

Discarding at the blooming mill does not simply mean something off the top of each ingot, but means a separation of sound portions of the ingot so that the material selected will be within the analysis specified.

Rod rolling must be done in such manner that the finishing temperatures are as nearly uniform as possible, for variations will result in variable tempers in wire which is drawn to coarse sizes without subsequent heat treatment such as annealing in process. The usual precautions against overheating or burning the steel are, of course, taken and naturally the rods are rolled at sufficient temperature to avoid finishing too cold. The atmosphere of the heating furnace should be controlled so as to prevent excessive scaling of the steel.

The rods before drawing into wire must be cleaned, sulled and lime coated. The advantages and necessity of the sull coat will be discussed later. In cleaning the rods sulphuric acid of sufficient strength is used at 180°F. to completely remove the roll scale and an inhibitor to prevent action on the steel is added to the bath. After cleaning, the rods are washed and placed on the sull racks. Sulling is done by spraying freshly cleaned rods with cold water and produces on the steel a coating of ferric hydroxide. For welding wire, it is necessary to have a uniformly dark and heavy sull coat so that the operation takes several hours to get the desired results. Should water be allowed to drip on the rods rather than be sprayed, the coating would be of ferrous and ferric oxide which would not adhere to the steel and which would scratch and cut out the drawing dies.

When the rods have received a satisfactory sull coat, they are removed from the racks and dipped into a bath of lime. After the steel is sufficiently coated with lime, the rods are baked in an oven several hours at a temperature of about 300°F. In baking, the rods are thoroughly dried and hydrogen which may have been absorbed by the steel in cleaning is expelled, thereby avoiding a condition known as acid brittleness.

The manner of drafting welding wire rods is governed by a great number of conditions. The finish strength of the wire and many other factors of more or less importance have to be taken into account in determining the number of drafts necessary to economically reduce the rods in diameter to that of a finished electrode. First, the general behavior of non-metallic surface material will be discussed and then the effect of increasing the tensile strength of a wire on its welding characteristics.

An interesting study of the effect of the surface material can be made by removing the natural finish and all traces of drawing lubricants by polishing on an emery wheel. If one attempts to lay down a bead on a plate with this wire, the arc is almost impossible to hold. It is, therefore, apparent that the electrodes most welders have always called "Bare Electrodes" are not really bare, but have something on the surface, which when removed makes an otherwise good wire unmanageable.

The surface of a so-called bare electrode usually contains mostly lime, sull coating and also a little soap or grease. During the process of drawing, the wire is in large coils not being straightened and cut for electrodes until the coil has been drawn to the finished electrode diameter. The wire is pulled cold through a series of dies, pass after pass, until the desired size is reached. If the wire did not have a proper lubricant during drawing it would break, cut out the die holes and make the drawing almost impossible.

Any slight variation in the steel going through the Wire Mill gives trouble in drawing and requires the wire drawer to change his dies or else change the reduction per draft. Such changes would, of course, cause a variation in the quantity of residual lime and sull left on the wire when it has reached the finished size, resulting in non-uniform behavior in the hands of a welder. A skillful welder and our modern generators take care of some variations in electrode properties, but the conscientious electrode producer endeavors to supply as uniform a wire as possible so as not to cause these hardships.

The principle function of the sull coating on an electrode is to stabilize the arc and this benefit is far greater than any aid that it may be to the welder in making the electrodes easier to manipulate. A good uniform sull coating increases the arc stability, because of reducing the arc vapor resistance. The molten metal in passing across a stable arc is in the form of a regular stream of fine particles. Loss of metal from sputtering is reduced to a minimum and the operator is able to hold a shorter arc if the electrode flows smoothly. The advantages of a short arc are greater penetration, less occluded oxide and nitrogen needles and sounder deposited metal free from blow holes. The electrode designed for holding a short arc is also more satisfactory for vertical and overhead welding.

The amount of cold work or drafting given a wire also affects the performance of the steel in electric welding because of influencing the melt-rate of the electrode. An annealed wire flows considerably faster than one which is drawn to a very high tensile strength. This feature is applied in a practical way when designing an electrode for a special type of work.

The residual lime on the wire decreases the speed

of the electrode, and in order to have samples of electrodes taken from one coil to perform the same as samples from another coil, absolute control and standardization of melting, rolling, and drawing practice is necessary.

A great deal of the processing to which welding wire is subjected is common to other wires of ordinary characteristics, but with the manufacture of welding wire it is an absolute necessity to go into every detail with extreme thoroughness. One coil of wire, when cut into 14" lengths is sufficient to do a considerable amount of welding and this fact demonstrates the need of a uniform product. In order to prevent shipment from a manufacturer's plant of non-uniform wire, the necessary thorough testing becomes evident, for with every precaution taken it is possible though not probable, for a coil of wire slightly off color, to be mixed in with better wire. A few pieces of such wire are sufficient to cause failure of some vital part of a pressure vessel or steel structure. One failure in a welded structure, especially a structure which has been given publicity, is enough to give welding a bad name and delay the advancement of the industry.

So as to eliminate completely the chances of adverse criticism of the welding industry, the manufacturer does his bit by thoroughly testing every coil of wire before straightening and cutting. Tests have been devised to show pipe, segregation and other steel defects by a nick and break test; for carbon content on a potentiometer and for welding by actual deposition of metal in flat, vertical and overhead positions. In this manner, the user of the wire is assured of material more than commercially uniform, for every coil that passes inspection will be of sound steel and correct analysis and will have the desired welding properties.

When considering the use of a welding wire, the consumer should bear in mind its chemical analysis, the tensile strength of the finished weld and the speed of deposition of sound metal, in flat, vertical and overhead positions. Other properties are often discussed but it is generally conceded that those mentioned will take care of the others satisfactorily. It is difficult to write a specification for welding wire, basing it merely on analysis and weldability as judged by individuals, for opinions on the welding properties of any wire are bound to differ. Several manufacturers are working on new specifications at the present time, which when completed will present an interesting departure from specifications now in effect. Reference to sound metal leaves a question open to opinion so that some means of measuring porosity must be set.

You gentlemen, as users of welding wire, should give a great deal of time and consideration to the wire in use in your respective plants. In too many instances, the kind of wire you use has been left to the opinion of one or two welders while no actual technical tests have ever been made to determine the type of electrode best suited to your particular work. You do not permit such conditions to exist in the selection of other materials and ask an electrician what type of electrical equipment to use, but select the equipment which in your own minds, based on your experience and the series of tests which you have run, best meets your requirements. Should not the same apply to welding wire? Or is it preferable to consider the opinion only of one or two men whose only qualifications might be the ability to hold an arc?

The manufacturer of welding wire has accepted his responsibility to the industry in attempting to produce wire of uniformly good properties, but he should never be held responsible for the misapplication of a certain type wire unless that wire, of course, was used on his recommendation.

The user must consider his responsibility but cannot properly accept it without using more care in the selection of the right wire for the right job.

Items of Interest

PERSONNEL CHANGES

One of the Association's staunchest friends, Mr. L. A. Umansky, General Electric Company, Schenectady, N. Y., has been temporarily transferred to Moscow, U. S. S. R., where he will be located for approximately two years. The good wishes of the A. I. & S. E. E. go with Mr. Umansky on this long trip.

The Reliance Electric & Engineering Company, Cleveland, manufacturers of alternating current and direct current motors, announce the advancement of M. C. Suerken to sales representative of its New York office and Robert M. FitzGerald to sales representative of its Philadelphia office.

The Shepard Niles Crane & Hoist Corporation announce the appointment of the Elliott Electric Company, 2178-2186 West Twenty-fifth street, Cleveland, O., and Mr. A. J. Acker, 1409 Keystone Building, Pittsburgh, Pa., as local representatives for the Sprague Electric Hoists and Winches.

Walter H. Wiewel has been made sales manager of The Timken Steel & Tube Company, Canton, O., replacing A. J. Sanford, resigned. Mr. Wiewel has been associated with the company for several years as manager of steel sales in New York City. He will make his headquarters at Canton, O.

George G. Landis, who has been identified with the Lincoln Electric Company, Cleveland, for the past eight years, has been made chief engineer.

H. Lee Reynolds Company of Pittsburgh has been appointed District Sales Representatives for the Roller Bearing Company of America, makers of "Heliflex" roller bearings. The Pittsburgh district office is in the Henry W. Oliver Building.

H. H. Angel, formerly general foreman of Electrical Department of the Bethlehem Steel Company, Sparrows Point, Md., has joined the staff of General Electric Company engineers who will assist the engineering staff of the Russian Electrical Trust in their work in connection with two new steel plants. Mr. Angel will be located at Moscow. Mr. Angel is a member of the A. I. & S. E. E. and his many friends throughout the Iron and Steel Industry wish him success in his new connection.

Bertram D. Quarrie has resigned as president of Oliver Iron & Steel Corporation, Pittsburgh, after three years in that office.

Edward C. Gainsborg has been appointed sales manager of the industrial division of the Roller Bearing Company of America, Trenton, N. J. Mr. Gainsborg was associated for many years with S.K.F.

Edward C. Gainsborg

Industries, New York, as manager of the steel mill division and of the Pittsburgh office. He has been a member of the A. I. & S. E. for many years and is well known throughout the Iron and Steel Industry.

Strickland Kneass, Jr., has resigned as chief engineer, A. M. Byers Company, Pittsburgh and Ambridge, Pa., to become affiliated with Leif Lee Company, Pittsburgh, manufacturer of heating and ventilating equipment.

WITH THE MANUFACTURERS

CARBON BRUSH MANUAL

This book differs from the ordinary carbon brush catalog, being designed to greatly simplify the selection and specification of carbon and metal-graphite brushes. The new shunt nomenclature of the National Electrical Manufacturers' Association has been adopted. The essential details for a complete brush specification are listed and discussed in the sequence which has been found most convenient. Tables of physical characteristics have been omitted. Instead, a cross index of grades and their applications simplifies the selection of a suitable grade for any service. Examples illustrate the manner in which the composite specification for a brush is derived. Copy may be obtained by interested parties from National Carbon Company, Inc., Cleveland, O.

The Anaconda Wire & Cable Company announce that they have acquired the Cable Accessories Corporation of Pittsburgh, Pa., with their complete line of Potheads, Junction Boxes, Joint Boxes, Insulating Compounds, and other cable accessories. These products will be manufactured hereafter under the close supervision of their engineers at Hastings-on-Hudson, N. Y.

Northern Engineering Works of Detroit, Mich., announce the opening of an office in Cleveland, O., in the Fidelity Building at 1940 East Sixth street.

F. H. Willcox, vice president of Freyn Engineering Company, returned March 29 on the "Europa". Mr. Willcox has been at England and the Continent in connection with various projects which the Freyn Engineering Company is executing abroad. Among these are the blast furnace plant for Ford Motor Company, Ltd., at Dagenham, England, and the blast furnace plant for the South African Iron & Steel Industrial Corporation, Ltd., at Pretoria, South Africa. Both of these projects are being designed and constructed by Freyn Engineering Company in association with Ashmore, Benson, Pease & Company, Ltd., the latter being the British associates of Freyn Engineering Company.

NEW BULLETIN DESCRIBING DEAD WEIGHT TYPE PRESSURE GAGE

A pressure gage which embodies dead weight tester accuracy and permanence of calibration together with abundant power for the operation of remote type indicators, recorders and control devices is described in a new bulletin entitled, "Power Type Pressure Devices," which is being distributed by the Bailey Meter Company of Cleveland, O.

The new bulletin No. 70 describes and illustrates Bailey Power Type Pressure devices explaining how the dead weight tester principle is combined with a Hydraulic Torque Amplifier and a Selsyn motor system of long distance transmission.

This power type unit in addition to serving as a pressure gage may be used for the operation of switches or for the direct positioning of small valves, rheostats or other equipment in accordance with pressure. Its principle use, however, as explained in the bulletin is for the operation of a Master Steam Pressure Indicating and Recording system where it is desired to have a number of indicators or recorders located at various stations.

HEAVY DUTY ROLL GRINDER*

Accuracy and smooth finish are essential factors in the grinding of mill rolls. In recognition of this fact, the Sharon Steel Hoop Company of Youngstown, O., installed a Farrell heavy-duty roll grinder in its strip and sheet mill during the latter part of 1929 to handle all hot rolls used in the manufacture of flat, single-pickled sheets of mild steel.

The grinder has been in operation less than a year, but the management is convinced that its investment is fully justified because of the improved quality of sheet steel produced with ground rolls. Also, the cost of grinding rolls as compared with the cost of turning on a lathe shows clearly that the higher quality is obtained without any increase in the cost of finishing the rolls.

As a matter of fact, it is found that the cost of grinding rolls is now slightly less than with the former method of turning in a lathe even though the

* Survey made by A. C. Nielsen Company.

grinder has a potential capacity from three to four times greater than the volume of work routed to it at the present time. The performance of the grinder to date shows that it possesses cost reduction possibilities of substantial magnitude which will be realized when a fuller use is made of the machine.

The grinder is now used for finishing heavy mill rolls of both chilled-iron and steel. The chilled-iron rolls are used in finishing mills and the steel rolls are applied in hot roughing mills.

The grinder embodies many features designed to increase the output, improve the quality of its work, and afford maximum convenience in operation. Rolls sent in for grinding are mounted and rotated toward a 30-inch motor-driven grinding wheel. The wheel is mounted on a carriage which permits lateral movement along a line parallel with the roll axis. An outstanding feature of the machine is the automatic crowning and concaving attachment. By means of an adjustable cam, the correct degree of concavity is automatically ground on the roll without any manual adjustments by the operator. The cam setup can be varied so that any desired degree of crown or concavity can be obtained.

The carriage traverses on inverted V-ways which are cast separate from the bed of the machine and are made of a special hard, close-grained iron. A self-cleaning automatic lubrication system and heavy guard protection assure uninterrupted and accurate service.

The wheel carriage is driven by a reversing motor through double-helical gears and a worm meshing with a rack on the bed of the machine. This construction takes the place of the ordinary rack and pinion. Push-button electrical control placed at the operator's finger tips permits every operation to be accomplished while the work is under the continuous observation of the operator.

ASSOCIATION NOTES

The Philadelphia Section of the A. I. & S. E. E. visited the plants of The Riverside Metal Company, Riverside, N. J., and the Florence Pipe Foundry and Machine Company of Florence, N. J., on Friday, May 1.

The members and their friends left the Engineers Club in Philadelphia at 9:00 A. M., and arrived at the Riverside Metal Company's plant at 10:00 A. M. The morning was spent at this plant. At 1:00 P. M., the party arrived at the Florence Pipe Foundry and Machine Company and were luncheon guests of this company. After lunch D. J. Peake, Superintendent of the plant gave a talk on the manufacture of Cast Iron Pipe. George Pfeffer described this plant in a paper which appeared in the December issue of the Iron and Steel Engineer.

On April 15, the Pittsburgh District Section of the A. I. & S. E. E. and the Youngstown Section of the A. I. E. E. held a joint inspection trip and dinner at Youngstown, Ohio.

Three hundred and fifty engineers participated in the day's activities. The Inspection Trip was through the McDonald Mills of the Carnegie Steel Company and the party left the Ohio Hotel at 1:30 P. M. The Inspection Trip was one of the best of the year and members, H. G. R. Bennett, assistant superintendent Bar Mills, and B. W. Gilson, superintendent Electric Light and Power, were responsible for arrangements of the trip through these modern mills.

At 7:00 P. M. dinner was served at the Ohio Hotel and C. S. McCalla, vice president and division manager of the Ohio-Edison Company, Youngstown, Ohio, was toastmaster. One of the features of the dinner was the Hon. Frank Crowther, U. S. Congressman from New York. The speaker made a wonderful address that was thoroughly enjoyed by the engineers present.

The Committee on Arrangements for the Inspection Trip and Dinner were F. W. Cramer, G. A. Kaufman, G. A. Hughes, F. C. Jeannot, C. S. McCalla, B. W. Gilson and H. G. R. Bennett.

OBITUARIES

Andrew Ellicott Maccoun, superintendent of blast furnaces at the Edgar Thomson works of the Carnegie Steel Company, Braddock, Pa., died at his home in North Braddock, Pa., on April 4. He was born at Baltimore in 1874 and attended Johns Hopkins University, from which he was graduated with the degrees of mechanical and electrical engineer. After leaving college he was identified for a time with the Thomas A. Edison Laboratories in New Jersey, and entered the steel business in 1895 as assistant superintendent of the electrical department of the Homestead steel works of the Carnegie company. In 1897 he was made superintendent of the electrical department in the Edgar Thomson works, and six years later became master mechanic. He had been superintendent of blast furnaces since 1905, and was chairman of the Carnegie company's blast furnace committee at the time of his death.

Beverly L. Worden, president, Cutler-Hammer Manufacturing Company, Milwaukee, died after a long illness at his home in West Orange, N. J., on March 28, aged 60 years. A native of Chicago, Mr. Worden was graduated from the University of Wisconsin in 1893. Eight years later he founded the Worden-Allen Company, of which he was president for the ensuing 20 years. In 1909 he established the Lackawanna Bridge Company, Buffalo, and continued as its president until 1924. In the war period Mr. Worden was general manager of the Newark Bay shipyard at Newark, N. J.

Frederick W. Bruch, president, Acme Machinery Company, Cleveland, manufacturer of bolt and nut-making machinery, died April 1.

J. G. Joseph, president and founder of the Buffalo Steel Company, Tonawanda, N. Y., died at the Millard Fillmore Hospital in Buffalo on April 2.

W. C. Holzworth, identified with the Pittsburgh office of E. J. Lavino & Company, Philadelphia, died suddenly at his home in Pittsburgh on April 2.

W. S. Robertson, who became associated with Combustion Engineering Corporation in 1912, died suddenly of heart failure on Tuesday, March 31, at his home, Hotel Riviera, Newark, N. J. Mr. Robertson was in his seventieth year and was actively engaged in sales work as Special Sales Representative for Northern New Jersey and Eastern Pennsylvania until the time of his death.

Charles A. Collins, vice president of the M. A. Hanna Company and president of the Hanna Furnace Company, Cleveland, died April 1, after a brief illness. He was also a director and vice president of the National Steel Corporation.

1931 PARTIAL LIST OF EXHIBITORS
At
IRON AND STEEL EXPOSITION
JUNE 15-19, 1931
CLEVELAND PUBLIC AUDITORIUM
CLEVELAND, OHIO

Air Reduction Sales Co.
Ajax Electrothermic Corporation
Ajax Flexible Coupling Co.
Alliance Machine Co.
Allis-Chalmers Mfg. Co.
American Air Filter Co., Inc.
Appleton Electric Co.
Atlas Car & Mfg. Co.
Automatic Reclosing Circuit Breaker Co.
Babcock & Wilcox Co.
Bailey Meter Co.
Bartlett Hayward Co.
Benjamin Electric Mfg. Co.
Bristol Company
Brown Instrument Co.
Bull Dog Electric Products Co.
Century Electric Co.
Clark Controller Co.
Cleveland Crane & Engineering Co.
Cleveland Switchboard Co.
Cleveland Worm & Gear Co.
Colt's Patent Fire Arms Mfg. Co.
Continental Diamond Fibre Co.
Crocker-Wheeler Electric Mfg. Co.
Crouse-Hinds Co.
Cutler-Hammer, Inc.
Davey Compressor Co., Inc.
M. H. Detrick Co.
Joseph Dixon Crucible Co.
John C. Dolph Co.
Edison Storage Battery Co.
Electric Controller & Mfg. Co.
Electric Service Supplies Co.
Electric Storage Battery Co.
Erie Malleable Iron Co.
Erie Steel Construction Co.
Fafnir Bearing Co.
A. D. Fishel Co.
G. & W. Electric Specialty Co.
General Cable Corporation
General Electric Co.
General Electric Lighting Institute
Great Western Fuse Co.
Harnischfeger Corporation
Hodson Corporation
Holophane Co., Inc.
Homestead Valve Mfg. Co.
Horsburgh & Scott Co.
Hyatt Roller Bearing Co.
Ideal Commutator Dresser Co.
Insulation Manufacturers Corp.
Iron & Steel Engineer
I-T-E Circuit Breaker Co.
Ivanhoe Division of the Miller Co.
Johns-Manville Corporation
Keystone Lubricating Co.
Krout & Fite Mfg. Co.
Leeds & Northrup Co.
Limitorque Corporation
Lincoln Electric Co.
Lincoln Engineering Co.
Lubrication Devices, Inc.
Lumen Bearing Co.
Manning, Maxwell & Moore, Inc.
Martindale Electric Co.
Monitor Controller Co.
Morgan Engineering Co.
Morganite Brush Co., Inc.
Morse Chain Co.
National Carbon Co.
New Departure Mfg. Co., Inc.
New Jersey Wood Finishing Co.
Nichols-Lintern Co.
Norma-Hoffmann Bearings Corpn.
Ohio Electric Mfg. Co.
Okonite Company
Otis Elevator Co.
Parker Appliance Co.
Penn Machine Co.
Pennsylvania Lubricating Co.
Philadelphia Storage Battery Co.
Wm. B. Pollock Co.
Pyle-National Co.
Reliance Electric & Engineering Co.
Roller Bearing Co. of America
Roller-Smith Company
Rollway Bearing Co., Inc.
Rowan Controller Co.
Schweitzer & Conrad, Inc.
Shallcross Control Systems Co.
Shoop Bronze Company
S-K-F Industries, Inc.
Square D Company
Standard Oil Co. of Ohio
Steel & Tubes, Inc.
Texas Company
Thompson Electric Co.
Timken Roller Bearing Co.
Tool Steel Gear & Pinion Co.
Trabon Lubricating Equipment Co.
Trumbull Electric Mfg. Co.
Una Welding & Bonding Co.
United American Bosch Corp.
United States Graphite Co.
United Engineering & Foundry Co.
Vacuum Oil Company
Westinghouse Electric & Mfg. Co.
Westinghouse Lighting Institute
Weston Electrical Instrument Co.
Edwin L. Wiegand Company

Wire Association Exhibits

Carboloy Company, Inc.
William Haddow Company
R. B. Hayward Co.
Lewis Machine Co.
Ludlum Steel Company
Master Wire Die Co.
Micro Products Co.
Morgan Construction Co.
New England Butt Co.
Sefton National Fibre Box Co.
Sleeper & Hartley, Inc.
Truscon Steel Co.
Union Wire Die Corp.
Vianney Wire Die Works